Utilisation of Crowdsourced Geographic Information for Benefitting Disaster Response in New Zealand

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Abstract

Crowdsourced Geographic Information (CGI) represents a new era in how we gather information, moving away from individual professionals to efforts involving the wider public regardless of qualification. CGI is of interest to both academics and spatial data users because it produces information at a rapid rate, and can be engaged to respond to events which require information from a changing environment. Naturally, this data is of considerable interest to disaster response agencies dealing with sudden events with a significant impact on known variables, such as where people live, or which infrastructure remains functional. At the time of writing, research in this field has been largely directed at overseas events, often in countries which have experienced events that completely overwhelmed their capacity for response. To this end, this study aims to fill that gap by focusing on crowdsourced research for New Zealand disaster response efforts, and investigates whether CGI can be beneficial here.

This research uses interviews with key experts in the field of disaster response, and uses thematic analyses of these responses to generate an understanding of how CGI can be implemented in disaster response. Through engaging with experts from Civil Defence and Emergency Management, Geospatial Intelligence New Zealand, South Island iwi Ngāi Tahu, and the New Zealand Red Cross, this study provides a broad view of CGI in New Zealand disaster management and how it is understood and implemented by these agencies.

Key findings of this study include: a need to find sources of information that can be updated with changing conditions; the need for a unified crowdsourced campaign to help deal with events; and how crowdsourcing can act as a support network for people after a disaster. This study presents a series of recommendations informed by expert opinions in this field and available literature, and which can be used as a guide towards implementing crowdsourced data in New Zealand. This study proposes a Citizen Response Network (CRN) framework, developed through the course of this research, which outlines how CGI can be successfully used to inform response and recovery. The CRN is designed with community engagement in mind to ensure the integrity of crowdsourcing as a product of citizen science.

This thesis adds to a growing body of work examining how we engage with CGI at a variety of levels, and through understanding how CGI has been perceived, and used, in New Zealand an objective assessment of its effectiveness can be made.

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List of Acronyms

CDEM	Civil Defence & Emergency Management
CCDEM	Canterbury Civil Defence & Emergency Management
CIMS	Coordinated Incident Management System
CGI	Crowdsourced Geographic Information – also referred to as VGI
CRN	Citizen Response Network
EMO	Emergency Management Office
EOC	Emergency Operations Centre
FEMA	Federal Emergency Management Agency (United States of America)
GIS	Geographic Information System
GNZ	Geospatial Intelligence New Zealand
HOT	Humanitarian OpenStreetMap Team
MCDEM	Ministry of Civil Defence & Emergency Management
NZDF	New Zealand Defence Force
NZRC	New Zealand Red Cross
OSM	OpenStreetMap
TA	Territorial Authority
UNISDR	United Nations International Strategy for Disaster Reduction
VGI	Volunteered Geographic Information – also referred to as CGI
VUW	Victoria University of Wellington, New Zealand

Chapter 1 – Introduction

Recently, spatial information, and information in general, has diverged in its collection from being solely the domain of professionals and their agencies to include private citizens and unpaid volunteers. This new approach is termed crowdsourcing, and comprises part of a wider process termed Neogeography or Citizen Science (Goodchild, 2007). Volunteered or Crowdsourced Geographic Information (VGI or CGI, respectively) is any information collected from citizen science sources (Goodchild M. , 2007), from ordinary people sharing information about their world in the form of observations, social media use, to processing geographic information. One of the important definitions of crowdsourcing is that the person involved is not being paid for their efforts, and in most cases are not formally training in producing geospatial information. This change in data collection has transformed information that was previously collected in time-consuming and expensive ways, often through surveys and direct data creation, into a new era where information is collected in near real-time and sometimes at no cost to the end user (Seeger, 2008).

In the field of disaster and emergency response and management, CGI is an information source with considerable potential to assist response agencies, especially as disaster events are becoming increasingly complex and consequential as a result of growing populations, increasing urbanisation and climate and other environmental changes. Natural events and their impacts on populations have been the focus of governments and international collaborations - the United Nations International Strategy for Disaster Reduction (UNISDR) (UNISDR, 2018) is a prime example of this. The UNISDR has now adopted the Sendai Framework for Disaster Risk Reduction (Prevention Net, 2018). The importance of the Sendai Framework in the context of this research is that information management plays a key role in reducing disaster impacts. By investigating how CGI can be used to better equip response efforts with reliable information, the aim of this project is to be part of this wider impact reduction initiative.

The research presented here is primarily concerning the Response and Recovery phase of the ‘Four Rs’. The Four Rs refer to the four stages of a disaster, in New Zealand defined as Reduction, Readiness, Response and Recovery (Civil Defence CDEM Framework, 2018):

- *Reduction*: Identifying and analysing long-term risks to human life and property from hazards; taking steps to eliminate these risks if practicable, and, if not, reducing the magnitude of their impact and the likelihood of their occurring.
- *Readiness*: Developing operational systems and capabilities before a civil defence emergency happens; including self-help and response programmes for the general public, and specific programmes for emergency services, infrastructure lifeline utilities and other agencies.
- *Response*: Actions taken immediately before, during or directly after a civil defence emergency to save lives and protect property, and to help communities recover.
- *Recovery*: The coordinated efforts and processes to bring about the immediate, medium-term and long-term holistic regeneration of a community following a civil defence emergency.

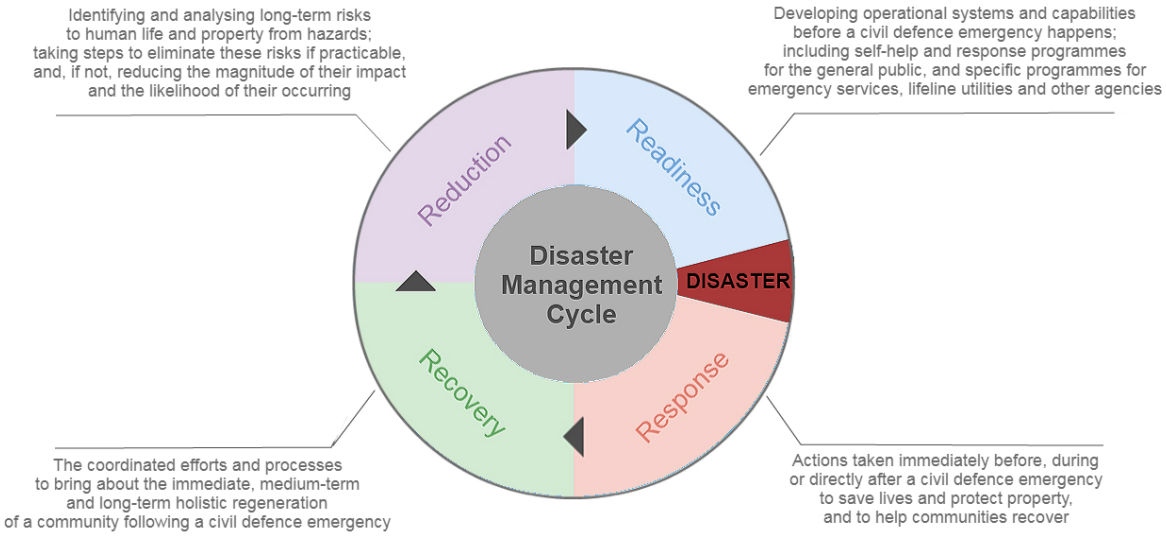

Figure 1: Disaster Management Cycle as described by CDEM (adapted from CDEM, 2018)

While information collection is part of Readiness as far as developing systems that are able to cope with disasters, the primary focus here is Response and Recovery. The reason for this is that the time in which CGI would be engaged with is after an incident when information not previously available, such as locations of damage, is needed. Additionally, after an incident Recovery can benefit from information about people and their situations to inform decisions regarding resource allocation.

Although the roles CGI has played in previous events and disasters have been documented in the academic literature, and CGI is an active research focus in some quarters, the extent to which New Zealand disaster response agencies understand and are implementing this approach to information collection needs to be further characterised. This thesis, using a combination of literature review and detailed interviews with professionals working in the disaster management field, seeks to answer the following question:

> *"How can Crowdsourced Geographic Information be utilised to the benefit of New Zealand governmental and other agencies' responses to disasters?"*

This thesis addresses this questions using information from interviews with key informants from the following agencies/organisations, to better understand how they perceive and use CGI, so as to benefit to disaster response efforts:

- Geospatial Intelligence New Zealand (GNZ), an arm of the New Zealand Defence Force (NZDF);
- Canterbury Civil Defence and Emergency Management (CCDEM);
- Emergency Management Otago;
- New Zealand Red Cross (NZRC);
- Ngāi Tahu.

This thesis is structured in the following manner:

- **Chapter 2** presents a literature review of CGI that describes its definitions and origins, and provides examples of CGI application through a series of international case studies. This is followed by recent case studies from New Zealand. The literature review informed the development of a series of questions that were put to the aforementioned New Zealand disaster response agencies; the questions are presented in Appendix A.
- **Chapter 3** presents background on the Methodology used for this research, describes the approach to the Thematic Analysis used here, and describes how the results are structured.

- **Chapter 4** presents Key Findings from the interviews conducted with New Zealand disaster response agencies, including how data are managed by and transferred between agencies across the Four Rs. This is followed by summaries of important Themes that were identified from the interviews.
- **Chapter 5** presents a Discussion of how the Key Findings fit within the wider international and New Zealand context of CGI use in disaster response, and provides Recommendations for development of CGI use in this area. This includes a proposal for a Citizen Response Network (CRN) to harness the resources of society and official agencies for best developing situational awareness after a disaster.
- **Chapter 6** presents a Summary and Conclusions from this research.
- **Appendix B** presents detailed synopses of the individual interviews conducted for this research; they constitute a rich resource for characterising institutional understanding and use of CGI.

Chapter 2 – Literature Review

Crowdsourced Geographic Information (CGI) has been a focus of research over the past decade. For geospatial scientists, it is a novel way to approach how we gather data about the world. As with all sources of data, however, it is not without its drawback. Despite these drawbacks, the application of CGI data analysis is being increasingly used. Among these applications several disaster response management, the focus of this thesis. The following literature review provides the necessary background to understand how CGI can be applied in a New Zealand disaster response setting, as well as placing this research in context with international efforts to understand how public participation in geo-science takes place. The literature review is divided into three sections:

- An introduction to CGI;
- CGI in disaster response; and
- A review of current research on CGI use in New Zealand disaster response.

2.1. Crowdsourced Geographic Information and disaster response

Crowdsourced Geographic Information as a concept is not new. For at least a decade, geographers have been considering the idea of the 'citizen scientist' as non-professional individuals or groups that record information about the world around them (Goodchild, 2007). While not a new concept, CGI in the context of disaster response research has become more of a focal point since its application in the 2010 Haitian earthquake (Zook et al, 2012). Goodchild (2007) posited the idea that every person living on earth has the potential to be a source of information when provided with a method to communicate. This idea was spurred on by 2007 having had "an explosion of interest in using the Web to create, assemble, and disseminate geographic information provided voluntarily by individuals" (Goodchild, 2007). Given how often Goodchild's seminal piece has been cited (3532 instances at the time of writing, Google Scholar) it would be fair to say that much research related to CGI would use this fundamental principle as a starting point. Specifically, the intersection of two ideas: 'citizen science' and 'citizens as sensors'. Citizen science is where people collectively work together in the interest of science or the understanding of an aspect of the world around them; as Goodchild (2007, p. 218) phrases it: "communities or networks of citizens who act as observers in some domain of science". Complementary to this is the idea of citizen sensors where people act as information collectors of their environment. Combined, these terms define VGI (from Sui, 2008):

> "Digital spatial data that are produced not by individuals and institutions formally charged as data producers, but rather, are created by citizens who use communication technology to gather and disseminate their observations and geographic knowledge".

This is to say is that individuals are volunteering their time, with a wide range of backgrounds and skills, to create data. These can be imagined in a variety of ways from a person posting on social media about a broken bridge, to an individual placing a point or line to represent a feature on an interactive map, to large-scale groups of volunteers taking the aforementioned information and collating them into a crisis map in a disaster event. The core element for deciding if something is VGI, based on Sui's (2008) definition, is that private citizens engage with the wider community to share information.

Research in subsequent years expanded upon this initial idea through understanding the nature of the data in terms of quality, rate of production, and perceived reliability, as well as understanding the significance CGI had to the people who contributed and the groups that used these data. In addition to these core elements of research is how CGI can be applied practically to real-world problem solving, the focus of this thesis. As an additional note it is important to differentiate between information that comes from the public outside of the context of disaster response and CGI used in relation to a natural hazard threatening an area.

2.1.1. Characteristics of Crowdsourced Geographic Information

Crowdsourced Geographic Information is characterised by being created by (usually) large groups of untrained individuals working collectively on specific projects that are either self-driven or directly without a for-profit motivation (Elwood, 2008). In general this represents the opposite of traditional or authoritative data generation and collection by trained professionals working alone or in small groups to create datasets on behalf of private (for profit) or government entities (Elwood et al., 2012). This characterisation also lends itself to five primary differences between CGI and traditional data collection: speed and scope of projects; ground-level insight; community facilitation; issues around data quality and trust; and finally accessibility.

The first and most noticeable feature of CGI is the range and number of people involved in projects. OpenStreetMap alone has 1.5 million registered users and local groups in more than

80 countries (Palen et al., 2015). Having groups of this size can lead to some significant advantages. Large user-base systems are characterised typically by fast production speeds and wide project scopes (Sui et al., 2012). Much of data generation is digitising or translating real-world data to a digital form, a process that is understood commonly to be time-consuming and has a high reliance on human input (Goodchild and Gopal, 1989). Crowdsourced databases, at least in regards to those that have high memberships/users, tend to be able to bypass this difficulty through employing a brute force approach. By engaging large numbers of participants, significant quantities of data can be digitised and mapped (Meier, 2012). This is even more apparent when a specific focus is given, such as a natural hazard-caused or anthropogenic disaster, and that same processing power is concentrated on a specific area or task (Triglav-Cekada and Radovan, 2013; McDougall, 2012). In comparison, from my personal experience working in the field of geographic information science, private (and government) data collection agencies implement smaller teams for repurposing existing datasets, or employ larger teams for specific data collection at significant cost. For example, CoreLogic (CoreLogic, 2017), a spatial property company based in New Zealand, and implements a team of more than 10 people to supply and maintain their spatial property database on a full-time basis. In contrast, crowdsourcing can provide labour without a high cost.

Crowdsourcing involves using the public, and as such CGI is in a unique position in that it can leverage local knowledge of its participants. Goodchild and Glennon (2010) make reference to this, saying "information obtained from a crowd of many observers is likely to be closer to the truth than information obtained from one observer". Goodchild and Glennon (2010, p. 233) use Wikipedia as an example of this, citing it as having become an "accurate encyclopaedia", and they references Giles (2005) who compared crowdsourced data in encyclopaedias. In this comparison Goodchild and Glennon (2010) and Giles (2005) note that 'enthusiasts' and 'amateurs' versed in particular subjects can provide better insight due to the greater amounts of time and effort put into learning the subject matter (over that of a professional encyclopaedia maker whose attention is split amongst several entries). In contrast, traditional professional cartographers and analysts often need to divide their limited time over several different projects or areas giving a limited perspective focused around the requirements of a project (Goodchild and Glennon, 2010). Local knowledge can yield advantage as it can reveal information that is either not available to a professional or unlikely to be discovered; however it also marks crowdsourced data as being intrinsically tied to producer motivations. That is to say, that crowdsourced producers, who are not paid, will work on projects driven by personal reasons

(Arsanjani, 2015; Quinn, 2015; Budhathoki and Haythornthwaite, 2013; Bégin et al, 2013; Coleman et al, 2009; Neis and Zipf, 2012).

Heipke (2010) examined user motivations and defined seven discrete user groups;

1. *Map lovers*: a small group who produce trustable and very valuable data, also known as Amateur mappers.

2. *Casual mappers*: Similar to Map Lovers but distinguished by the fact that they are only willing to spend a relatively low effort for mapping, preferring to add data over editing existing datasets.

3. *Experts*: active people and leading map users in organisations such as mountain rescue, fire brigades, civil protection, or traffic guides. They are motivated by the feeling that they may make their own life easier, they can contribute with very valuable and trustworthy data, both old and new. Notably not usually considered as crowdsourced data producers but are likely points of interaction with CGI.

4. *Media mappers*: groups of contributors, activated sporadically by regional to international media campaigns. Typically singular and independent event-based, motivations are often driven by accomplishing a specific task. In disasters, this is a common form of contributor group, as providing aid in a disaster provides strong motivation.

5. *Passive mappers*: data derived from location-enabled technologies such as mobile phones, GPS, and social media software. These data are drawn often from contributors unaware of the use of their personal data or drawn from a volunteered source without the direct purpose of it being used for mapping (e.g. a Tweet about a disaster using used to locate an incident).

6. *Open mappers*: Noted as the largest of all the groups, the users of this technology can come from any of the first four categories above, however are typically from the first two. This group contributes to ongoing geospatial datasets classified as open-source, such as OpenStreetMap (OSM). Increasing attention in this category is on accuracy and coverage, with the datasets now rivalling existing databases such as Ordnance Surveys (Flanagin and Metzger, 2008; Harklay, 2010; Neis et al, 2013; Zielstra and Zipf, 2010).

7. *Mechanical Turks*: Individuals who conduct this kind of "volunteer" work for pay. Heipke (2010) notes that this group is important to include because they have large mobilisation powers and can be used for data validation provided accurate base information exists (e.g. high resolution imagery).

These groups represent most non-professional individuals and groups that create CGI. Most notable is the range of skills, methods of organising, and motivations associated with these groups. This is important to understand as it is clear that not every source of volunteered data is the same, and depending on the experience and motivation of the source it is possible to gather very different information from different groups.

Alongside the categorisation of different types of contributors, the impact of local knowledge becomes clear. This is demonstrated in the literature by the personal insight of volunteers improving map data. Coleman et al. (2009) term a group that does this particularly well as 'Neophytes'. 'Neophytes' are casual mappers with very little experience and motivated by an interest in mapping and a desire to communicate. These mappers are identified as being particularly useful for their local knowledge, often identifying inaccuracies in data that relate to where they live or have something to do with socially, economically or otherwise (Coleman et al., 2009). In practical terms this is exemplified in how users of OpenStreetMap map their local environments to a higher quality than some governmental road datasets (Arsanjani et al., 2015; Haklay, 2010; Chilton, 2009). Arsanjani et al. (2015), Haklay (2010) and Chilton (2009), in their studies on OpenStreetMap, focus on the power of local knowledge in relation to contributors' immediate environments. To quote Haklay (2010): "The most important value of VGI may lie in what it can tell about local activities in various geographical locations that go unnoticed by the world's media, and about life at a local level". Chilton (2009) puts this into context with their study revealing that only through local knowledge was the damage of the United States Route 90 Bridge identified while response agencies were unaware until this was highlighted by a member of the public. The value of local knowledge was summarised by Arsanjani et al. (2015): the temporal nature of local knowledge in which only people who live and experience their local environments will ever truly have the most up to date and accurate understanding.

CGI comes primarily from untrained individuals. This is a fact of these types of data, and despite some users being amateurs with good reputations most are classified as casual (Heipke, 2010). Data from untrained casual mappers carry the risk of inaccuracies and errors that would

be much less likely in a professional dataset. Because of this inherent risk, CGI data quality has been the subject of considerable research that does not yield a clear solution to the accuracy issue. What is clear, however, from research examining disaster data (Goodchild and Glennon, 2010; Poser and Dransch, 2010; Zook et al., 2010) and the data of OSM as compared with official state datasets in different regions (Girres and Touya, 2010; Heipke, 2010; Neis et al, 2011), is that there is potential for high-quality information in crowdsourced datasets. Data quality in CGI is related to: the systems of collection and the presence of internal moderating mechanisms in them; the volume of participants, with higher-quality data associated with high contributor numbers; and contributor background and motivational groups indicating quality. As such, and for the purposes of the research presented in this thesis, data quality will be considered a factor of CGI viability in New Zealand, but not the primary concern in this area. Instead, this research will focus more on 'trust' in or perception of crowdsourced data in general, rather than the quality of specific CGI datasets.

"Trust" in this thesis refers to a held perception of quality of a type of data, specifically whether response agencies trust crowdsourced data enough to use it. This question of trust is significant as it is one of the factors in government agencies adopting CGI. Johnson and Sieber (2013) noted that in their experience there is initial enthusiasm around CGI implementation, however this is dampened by later concerns around integration and viability of data (an aspect of trust). Johnson and Sieber (2013) highlighted that one of the issues for governments in accepting 'non-expert' data are questions of who are the contributors. Lee (2016) supported this in their research on integrating CGI into South Korean government data infrastructure. The authoritative agencies in this instance understand the benefits CGI yields, however were concerned at the lack of quality assurances with regards to who is producing the data. These two examples support the more general viewpoint presented by Goodchild (2007), Meier (2012) and Haklay (2010) that CGI is a powerful tool but there is a general lack of understanding that prohibits the same trust as is given to authoritative databases. In New Zealand's case, research by Beatson (2016) indicates an element of trust in CGI from the New Zealand response agencies, primarily Civil Defence and Emergency Management (CDEM), with the proliferation of a crisis map with strong CGI elements. This is discussed in more detail below, but for now it can be stated that more direct efforts are needed to gauge New Zealand emergency and disaster response agency perception of CGI trustworthiness. The following section will feature a variety of international case studies that will form a foundation of how CGI has been utilised overseas.

2.2. Crowdsourced Geographic Information in disaster response (international case studies)

The previous section defined CGI and described how its elements centre on public engagement that can appear in differing forms. To contextualise CGI, international case studies offer a unique insight into how these data has been actively applied. While previous research in New Zealand is ideal for framing the scope and informing the findings of this current study, this research is relatively sparse. The following section highlights four key case studies and examines the lessons learned in each. These lessons will be a point of comparison for the New Zealand case and will better inform the New Zealand-centric research of this thesis.

2.2.1. Kenyan election crisis 2007-2008

During the period 2007 to 2008, the election for Kenya's president caused a massive political crisis that was marked by protests, civil unrest and violence that left many displaced from their homes. This unrest stemmed from the news that Mwai Kibaki had won, a result which was attributed to a suspected rigging of votes (Beatson, 2016). Following the result, and ensuing violence, the government issued a five-day ban on reporting and the censoring of media that was released. This created a need for methods of communication beyond the media. Social media and collective information (crowdsourcing) was found to be an effective alternative. Central in this new method was the activist and lawyer Ory Okolloh and the 'Ushahidi' platform (Okolloh, 2009).

On the 3rd of January 2008 Okolloh put out a call on her blog for 'techies' in Kenya to build a website for the public to communicate with. The domain registered was called Ushahidi which means 'testimony' in Kiswahili (Okolloh, 2009). This platform grew quickly and incorporated mobile SMS messaging into its data flows. This encouraged the participation of Kenyan citizens, as while many did not have access to the internet (3.2% estimated by Makinen and Wangu, 2008), and 50% of people had access to mobile phones, as reported by the Communications Commission of Kenya (Chiloba, 2012). News of this platform spread with even some radio stations using the reports posted on Ushahidi in their broadcasts (Okolloh, 2009). Ushahidi allowed for the collection of anything that citizens felt like sharing, such as locations of violence, and notifying they had been displaced (Kahl et al, 2012). This created a wide spectrum of available crowdsourced data, the output of which was used by two main groups: response agencies and individual citizens.

Beatson (2016) discussed how this variety of data created good situational awareness for response agencies. Gao and Barbier (2011) noted that Ushahidi, for the Kenyan crisis, facilitated social activism and a level of public accountability to contribute to a collective visualisation of incidents that were used by various organisations. This level of information is what response agencies are looking for. In contrast to this, Ushahidi at the time was used by individuals for information that concerned them personally and their family. Beatson (2016) identified this specific personal use as 'hotspots': individuals sought out information around their local area to keep informed. This proximity to information is also fed back into the system by individuals close to 'hotspots' of violence or activity having the motivation to contribute to Ushahidi.

In the application of Ushahidi for this crisis, questions of trust in these data were raised (Beatson, 2016; Martin-Shields and Stones, 2014; Okolloh, 2009), however this has been viewed as the need for improvement as opposed to a critical issue with the data. In regards to trust, Martin-Shields and Stones (2014) made an interesting observation that individual likelihood to trust crowdsourced data largely comes from who presents it, rather than information content itself. Specifically, Martin-Shields and Stones (2014) noted that "if crowdsourcing works, then our results indicate it is because of two steps. The first is that people share information via mobile phone; the second step is that this information is broadcast on a trusted medium such as radio" This raises an interesting question of how the method of presenting crowdsourced data to response agencies will influence their use of it.

Kenya as a case study represents an important foundation for all research on crowdsourcing for disasters. This humanitarian crisis was the first major deployment of an independent project to collect data from the public, separate from response agencies. It also was considered a very successful initial deployment as it created a medium for collaboration that was in this case limited by either technology or media suppression (Okolloh, 2009). Okolloh supports this with a quote from Randy Newcomb, President and CEO of Humanity United: "In Kenya, Ushahidi demonstrated the power of geographically mapping real-time citizen reports and crisis-related information to help civilians avoid conflict". Evident from the other case studies below, Ushahidi has been widely utilised. This raises the question - *To what extent are response agencies in New Zealand aware of Ushahidi and its applications?*

2.2.2. Haitian Earthquake, 2010

On January 12, 2010, a Magnitude 7.0 earthquake struck Haiti (Beatson, 2016). This earthquake was a disaster at a national scale with estimates of more than 200,000 dead, approximately the same injured, and 2.3 million displaced (Dugdale et al., 2012). In addition to deaths and displacements, massive infrastructural damage severely impeded response efforts, with the city of Leogane having up to 90% building collapse (Heinzelman and Waters, 2010). Within all the destruction caused by the earthquake there was one important infrastructure with relatively little damage: cellular phone towers, with "most towers still operational" (Meier and Munro, 2010, p. 92). Following the earthquake national and international aid was dispatched with the initial primary agency being the United States (US) military (Munro, 2010). Much of the local aid in the form of the 9000 United Nations (UN) troops under MINUSTAH (a French acronym for this UN mission), was dispersed and initially ineffective with their headquarters destroyed by the earthquake.

As was the case in the Kenyan election crisis (Section 2.2.1), the initial crowdsourced data seen was in the form of Ushahidi SMS messages. However, the information was in Haitian Kreyol and most labour efforts in the first phase of CGI response were around translation, with 40,000 messages translated in the first six weeks. In addition to Ushadidi, local infrastructure information was sourced through OSM but this was noted by Soden and Palen (2014) as only presenting a portion of the road network. The presence of situational awareness information (from people in need), through SMS, and infrastructure from OSM, would experience a dramatic evolution in the subsequent weeks.

Ushahidi, with the aid of volunteers translating messages for its crisis map, followed a similar pattern as in the Kenyan election crisis, including the development of a publicly viewable crisis map. Yates and Paquette (2011) observed that response agencies used these data and noted that their systems also resembled those of 'social media'. The Air Force Crisis Action Team (AFCAT) was a key agency in this, tasked with providing intelligence to US Air Force command. The information presented by Ushahidi was a focus point for AFCAT (Yates and Paquette, 2011). For the purposes of internal collaboration (excluding the citizens providing much of this information) Microsoft SharePoint was used, a system Yates and Paquette (2011) argue is 'social' in the way it disseminates information widely for collaborative involvement, including 'on the fly' pages being added and comment systems. A move towards both crowdsourced data and a crowdsourced-like method of information sharing was a noteworthy

feature of this case study, as it demonstrated lessons learned from public involvement. Ushahidi in future deployments of the platform will follow a similar pattern: a need/emergency; a small group activating the Ushahidi platform; a crisis map being formed alongside a public request for data; growth of volunteer group; and map detail as the situation develops (Yates and Paquette, 2011).

Separate to Ushahidi implementation was the development, parallel to military activity, of the Humanitarian OpenStreetMap Team (HOT), a dispersed group of OpenStreetMap users focused on rapid development of spatial data post disaster (hotosm.org, 2017). As Soden and Palen (2014) noted, Haiti roads were not featured heavily in OSM before the earthquake and in response to this a more formal group within the informal OSM users was established. While previously existing, HOT rapidly solidified as a more structured group as a result of the tropical storm Ondoy in the Philippines (Maron, 2009). The impact of this focused group was significant, as seen in Appendix E (OSM progression with HOT intervention). In less than a month the OSM map of Port-Au-Prince became as detailed as Ordnance Surveys from western countries. This map was invaluable to response agencies because information coming from Ushahidi and their own responders could be located spatially with a high degree of accuracy (Zook et al., 2010). This form of direct mapping by the public was also demonstrated in Google Map place marks for important features and issues. These place marks, often contributed to by people internationally, were made possible by the donation of high-resolution images from private companies such as Google and Digital Earth. Although this type of crowdsourced information is beyond the scope of what formal agencies could also, it was vastly more effective as they required no mapping resources.

In the immediate aftermath of the earthquake there was a need to identify structural damage in populated areas. However there was no system to mobilise structural engineers on the ground to conduct structural assessment surveys, and even with individuals able to do the job there were not enough to work at the speed disaster response required. To this end, and with the release of high-resolution imagery, a community of volunteers formed to use remote sensing technologies (satellite imagery) in place of people on the ground. This group was the Global Earth Observation Catastrophe Assessment Network (GEO-CAN) (Ghosh et al., 2011). GEO-CAN worked quickly and within 48 hours produced a map of high collapse (buildings) areas (Appendix F). This continued as higher resolution imagery emerged, including photos from the ground, resulting in even more detailed maps. These were used to assist the decision-making

processes of response agencies; however they were not useful to individual Haitians (Ghosh et al., 2011).

This disaster also marked the novel implementation of a project called ‘Tweak the Tweet’ which was led by Kate Starbird (Starbird, 2011). Initially presented at the Random Act of Kindness workshop in 2009, the idea was to ask users on the Twitter platform to use specific ‘Hashtags’ (an internal tagging system of ‘Tweets’) and formats for presenting critical information. During a disaster people could use Twitter’s own internal search Application Programming Interface (API) to find the messages affected people wanted to get out. With correct Tweet formatting these individual messages could then be translated into the Google Map platform. The output of this showed that few people followed the proposed format, however 74 users re-Tweeted posts in the correct format resulting in 3000 unique posts or calls for help (Starbird, 2011).

Beatson (2016) summarised the work of three studies (Morrow et al., 2011; Munro, 2012; Dugdale et al., 2012) that assessed the application of Ushahidi in Haiti. They agreed that Ushahidi presented its data in a way that targeted response agencies by identifying ‘centres of gravity’ which could be used to focus resources, as opposed to individual crises and rescue needs. This was favourable from the response agency perspective and also worked to alleviate some hesitation around accuracy concerns. Dugdale et al. (2012, p. 714), in an interview with an emergency manager, found that individual reports were “not very accurate…up to 90% of the reports of people trapped…were not correct”. This contrasted with the same person’s comments that the aggregated information was found to be “80%...correct at the area level”. Agencies in the Haitian earthquake viewed CGI positively, which is supported by a special report by the United States Institute of Peace (USIP) (Heinzelman and Waters, 2010). In this report it is noted that Ushahidi reports were used directly by US response agencies including the U.S. Federal Emergency Response Agency (FEMA), the US Marine Corps, and the U.S. Agency for International Development. In a Tweet from FEMA’s Craig Fugate, “the crisis map of Haiti represents the most comprehensive and up-to-date map available to the humanitarian community” (Heinzelman and Waters, 2010, p9).

Much of the research around the Haitian earthquake focused on what can be provided by crowdsourced data to disaster response. The question that is absent in much of this work is how well do response agencies use these data. There are few articles which try to address this question. It is important to note that the above examples indicate a volunteer/individual driven

crowdsourcing effort, so the uptake of CGI by response agencies should be viewed in the light of information being presented to them instead of information driven by their needs.

Resulting from the Kenyan election crisis case study (Section 2.2.1) and the evident usefulness of Ushahidi in that situation and in Haiti, a consequent question is: *are New Zealand response agencies aware of its use?* However even in the space two years of several new forms of crowdsourced data or groups working with crowdsourced data have developed, from Ushahidi's crisis maps, to OSM developing and the HOT groups. This leads to a second part to that question: *are New Zealand organisations focussing on identifying evolving forms of data collection or new sources becoming available?*

2.2.3. Chilean Earthquake 2010

On February 27 2010, Ushahidi was activated again in Chile (Beatson, 2016). On this day, a Magnitude 8.8 earthquake struck causing the deaths of 521 people, with half of those being from the subsequent tsunami. The earthquake was located 8 km from the coastline and those in the closest city, Chillan, experienced a total loss of infrastructure including having no water, gas, sewage, electricity and unlike Haiti, no communications, with the telecommunications network crashing from overload of calls and SMS. This system (cellular) recovered slowly and was hindered notably. As this system recovered Ushahidi began to receive information and specific Twitter hashtags were monitored. Unlike Haiti, however, this case study had a powerful instance of resources being misused due to grossly incorrect information (Beatson, 2016).

The Ushahidi Chile crisis map was set up within 48 hours organised by Patrick Meier and David Kobia. Meier, who at the time was speaking at Columbia University's School of International and Public Affairs (SIPA), had 60 SIPA volunteers trained by March 1st and working to process incoming reports. The view of Ushahidi leaders was that information would be largely similar to that found in Haiti, with the difference that for the Chile crisis map focus would not be on specific problems or issues and instead focus on information provision to "media organizations, civil society organisations, and Chileans about the situation from collapsed buildings, available food drives, and areas experiencing heightened looting" (Carlsen et al, 2011: from Beatson, 2016, p. 67). However, some information was used in a very direct manner resulting in an unnecessary deployment of personnel and emergency services needed elsewhere.

During the deployment of the crisis map two reports were uploaded onto the Ushahidi platform. One said 'Please send help, I am buried under rubble in my home at Lautaro 1712 Estacion Central, Santiago, Chile. My phone doesn't work'. Another was from a tweet reading 'RT@biodome10: plz send help to 1712 estacion central, Santiago chile. Im stuck under a building with my child. #hitsunami #chile we have no supplies' (Ayala 2010 from Beatson, 2016). This was forwarded to the police by a member of the public who saw the report on Ushahidi. The response was significant with three fire trucks, 30 police members and the chief of security responding. The location turned out to be undamaged and no one was harmed. This hoax report highlighted two important issues; first is question of reliability of crowdsourced reports; the second is access to sensitive information by the public contributing or observing. Research on the subject does note however the benefits public access to information and communication has, particularly in regards to Twitter use during the Chilean earthquake (Ayala, 2010, from Beatson, 2016).

Twitter has been featured in the literature regarding the Chilean earthquake. This research however concerns primarily post-event analysis of Tweets and their potential application over actual use examples. One such paper, Ahmed and Sargent (2014), examined how Twitter was used as a communication tool in this disaster. Their findings suggest that amongst 500 tweets analysed there was a clear trend towards individual community members being the most prolific Tweeters. Furthermore Ahmed and Sargent (2014) found that the 140 character limit in Tweets resulted in concise messages that combined with attached images/URLs delivered effective information. They also found that very few senders of Tweets during this period were from official agencies. This lack of involvement from official agencies such as the Ministry of National Defence suggests that during this period there was limited engagement of the community and response agencies via Twitter. Finally, Ahmed and Sargent (2014) examined in their study how Twitter was used amongst the community for communicating/organising tasks. While they did not mention specific tasks undertaken, Ahmed and Sargent (2014) noted the way in which re-Tweeting information allowed for rapid dissemination of Tweets relating to specific problems. These authors characterised Twitter as a net positive influence on recovery after a disaster. This positive viewpoint on non-emergency responses (those that do not pose imminent risk to life) is supported by Beatson (2016) in her analysis that identified Radio Bio-Bio as a key user of crisis maps to support local community operations, in this instance helping source potable water.

In contrast to the example of the crisis map being misused, Twitter response to people in danger was noted by one pair of authors as yielding an unequivocally positive result. Paris and Rubin (2013) followed a case study of a missing British couple and the mobilisation of cooperative efforts over Twitter and the internet to assist in finding them. A family member of one of the couple engaged with Twitter seeking aid in finding their location post-earthquake. The outcome of these efforts was good, as the couple was found shortly after these efforts began. Paris and Rubin (2013) also note that this case study highlights different technologies and websites that assist in locating people after a disaster such as Facebook's 'check in' system, Google Person Finder, and even Couchsurfing.org are used, and indeed were used in finding this couple. This highlighted that although direct information can be misused, it can also produce outcomes that are noteworthy testaments to what social media can do to link and mobilise people.

In the above studies a consistent theme is present: the pervasive risk of being burdened by either incorrect, irrelevant or too much information. Cobo et al. (2015) sought to solve this through technology and the automatic classification of Tweets for relevance. Cobo et al. (2015) used Chile as a sample for this in assessing their application named 'Citizen Channel'. Related work identified by Cobo et al. (2015) began with manual classification of information. This is what crisis mapping mostly involved as teams of volunteers worked to process data, however clear limitations including language barriers and large datasets were a constant. Further detailed post-processing, or secondary information such as patterns amongst datasets are also examined by Cobo et al. (2015). The examination of metadata, such as where is information coming from, and looking for areas of data concentration as an indication of need, an element that has application to disaster response as finding patterns can indicate where resources can most affectedly help people. Finally, research on creating tools to process and view these data live in a real situation was also examined. This analysis of data through software may offer solutions to the issue with massive datasets posed by crowdsourcing through social media (Cobo et al., 2015)

The 2010 Chilean earthquake provided insights to the impact social media can have on disaster response, and two possible outcomes of using crowdsourced data; successful direct response and misappropriation of crucial resources. Both stem from social media being a staple in how people communicate after a disaster. Citizen engagement through social media yields positive results, although direct intervention needs further investigation. However the potential amount of CGI is immense and this could act as a deterrent to response agencies actively engaging with the public over these platforms. There are solutions to managing high data volumes but these

appear to have only recently been applied to CGI and this poses an interesting question: *are New Zealand response organisations aware of and able to implement new technologies to aid use of CGI?*

2.2.4. The 2011 Queensland Floods, Australia

Between December 2010 and January 2011 an unprecedented amount of rainfall occurred in Queensland, Australia (Bureau of Meteorology, 2011; from Beatson, 2016). The impact of this, in the words of the Bureau, was 'one of the most widespread and significant floods in Queensland's history'. A Flood Emergency was declared during this period in response to damage and the loss of 38 lives (Beatson, 2016). This event differed from situations above where the onset of emergencies and the speed of response efforts would differ greatly based on location and when during the floods it occurred. For instance Toowoomba, an area in south eastern Queensland, experienced flash flooding to the degree that waterborne debris included vehicles (Bruns et al. 2012; from Beatson, 2016). Toowoomba was not isolated in this and a number of locations were also struck suddenly. For this event, while flooding occurred over the entire period, the focal point of crowdsourced data was on Twitter between the 10th to 16th of January 2011, with 11,600 Tweets featuring the Hashtag #qldfloods on the 12th January alone at the height of the flooding (Beatson 2016), as well as a Ushahidi based crisis map launched by the Australian Broadcasting Corporation (ABC) organisation.

Compared to the events in Kenya, Haiti and Chile (Sections 2.2.1-2.2.3), the unique elements of the Queensland flood concerned who was responsible for creating and disseminating the crowdsourced crisis map, how research characterised social media as an accelerator of public service information, and how photographic evidence of damage and flooding was used to derive trustworthy reports and even a digital spatial model of the flooding. As discussed in the case study of Kenya, some of the trust in crowdsourced data comes from who it is presented by. The Queensland Floods provide insight into how a reputable agency, in this case a media organisation, could impact agency perception of crowdsourced data.

Posetti and Lo (2012, cited in Beatson, 2016) discussed the timeline and approach the ABC television network took in producing their Ushahidi platform crisis map. From the outset the crisis map produced was not actually created with the floods in mind. It was instead a trial for the ABC to map feral animal sightings with possible secondary functions to map and display emergency and news story information. Because of this Ping Lo, as well as the ABC's national

social media coordinator, noted that the map was produced with what she termed as a 'talkback [radio] caller' mind-set. This is to say that it was an open platform for introduction of information. The platform was used to publish information that could not be verified immediately but represented enough public interest to justify reporting on, with appropriate caveats attached to this information.

ABC's crisis map attracted significant attention with 1500 reports being submitted over its lifespan. These reports, particularly those from the public comprising one third of all reports, were aided by being categorised from the outset as to whether they were property and road damage, power outages, and sewage spills. Ross and Potts (2011, from Beatson, 2016) noted additionally that ABC displayed more 'stationary' and verified information from official sources (such as Queensland State Emergency Service) allowing the crisis map to serve as a source of information to the same people providing information useful to response agencies. This synergistic relationship between the community who knew the ground situation and needed information about services, and response agencies who wanted to communicate emergency information and needed to know what areas were in danger, presents an interesting question: h*ave New Zealand response agencies considered the use of social media or platforms such as crisis maps as a way to create a constructive dialogue, between CGI providers and official agencies, during emergencies?*

Disseminating information effectively to the public during a crisis can be just as important as collecting information. To this end, Professor Axel Bruns of the University of Queensland worked with several other researchers, across three papers (Bruns et al, 2012; Bruns and Burgess, 2013; Bruns, 2014), to understand the role Twitter had in the Queensland disaster. Their findings highlighted the highly effective nature of the Twitter platform for spreading information, as well as the use of embedded images in Tweets for understanding the situation in affected areas. Additionally Bruns et al. (2012) found that response agency involvement on social media during this period was high, in contrast to previous case studies where response agencies were not as involved.

A report by the Centre of Excellence for Creative Industries and Innovation examined the role social media environments had on effective communication in crisis situations (Bruns et al, 2012). Specifically, they looked at Tweets under the #qldfloods Hashtag. The report found that Twitter in the Queensland floods supported community empowerment through locals being able to stay connected and informed, while also noting that their findings were centred around

populated areas and this implies there may be people who are missed in social media CGI (Bruns et al., 2012). The report also noted significant involvement of response agencies on social media with 'emergency services…amongst the most visible participants in #qldfloods'. This deviated from the previously established norm of response agencies observing the outputs of crowdsourced data collection with greater distance and less involvement. One possible reason for this change is the direct involvement of Queensland police in the social media crowdsourcing effort under the Twitter handle @QPSMedia (Queensland Police Service Media Unit). This direct involvement helped recovery through improved information flows both ways, notably having each Tweet by @QPSMedia being re-Tweeted 25 times on average. Twitter, and social media as a wider category, represent an emerging form of communication. As such it would be appropriate to ask New Zealand agencies: *how do they engage with social media and how this has changed over time?*

2.3.1. Crisis Maps and data collection – the 2010-2011 Canterbury Earthquake Sequence, New Zealand

In simple terms a crisis map is any map that appears after a disaster and displays content specifically for parties concerned with the ground-level situation (Beatson, 2016). To this end Beatson (2016) provides a detailed account of the creation, and consolidation, of crisis maps after the 22 February 2011 Christchurch earthquake:

> "The Christchurch Recovery Map (eqnz.co.nz) was launched within 24 hours of the earthquake (McDougall 2012: 207). Initially three maps with overlapping objectives were deployed by the organisations Eagle Technology Group, a community volunteer group based in Wellington (using the Ushahidi platform) and Stuff (a news service under the Fairfax Media group); and it was only after negotiation that one map was agreed upon to 'maximise efforts and reduce duplication' (McDougall 2012: 207). The Christchurch Recovery Map was run entirely by volunteers with the majority of members based in Wellington (Forde 2011), but with international participation from over seven different countries."

Beatson (2016) describes a situation in which multiple crisis maps were established and some disestablished within a very short space of time. The variety of maps is important because they demonstrate the range of producers involved. For example, one producer, Eagle Technology, is a large company with significant resources and paid staff, while the community volunteer

map is the opposite with limited resources and a higher time cost to individuals working on the maps. While producers differed, their goals intersected in wanting to help understand what has happened in the disaster and to present that information to agencies and the public. The challenge is to identify where these groups intersect. This diversity is a key theme presented in Beatson's (2016) work, as is the overcoming of institutional differences to produce a unified information portal of public use.

The crisis maps in Christchurch acted as a primary source of information for both Emergency Management Offices (EMO) and the public. A centralised information source in this case acted as a factor improving situational awareness of all users. Beatson (2016) describes how the disruption from the earthquake created a 'New Normal' (Taylor 2011, cited in Beatson, 2016). This new normal refers to the removal of base utilities and communications caused by the earthquake, as well as the disruption to everyday activities such as work. As such residents of Christchurch, and their family and friends wanting to know more about their situation, quickly became information-dependant for even the most basic services such as where to get water. This need for information was met with another issue: traditional sources such as news media (often daily papers) were, when even available, filled with rapidly outdated information that was too broad for practical use. This lack of information drove the need for new sources of information much more specific and designed specifically to support situational awareness for residents and response planners. Crisis maps fill this gap by giving an avenue for information on a local scale, like sources of food, water and shelter. Information such as this had real and tangible value to residents and allowed planners to get a ground level understanding of the situation. Furthermore because much of this information was being provided by the residents it was specific and directed to individual families' needs.

Situational awareness is a key determinant of the success of strategic planning for large EMOs and local community response. Beatson (2016) along with Paton et al. (2014) discuss this for the Christchurch event. This is referred to in Beatson's (2016) work as the 'self-organising capability of communities' and is related to the idea of community resilience. A summary of this concept states resilience as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard" (UNISDR, 2009, from Beatson, 2016). Strategic information is an important part of resilience as was discovered. With accurate and timely information local communities can more effectively come together to find solutions to problems posed by a disaster. For example crisis maps were noted as being a good aid to community based resilience by being a primary information source

(Beatson, 2016). Paton et al. (2014) note that in the aftermath of a disaster factors like isolation and loss of social media have a significant impact on individual resilience, and that communities coming together has a large impact on the welfare of people, further highlighting the critical nature of information in a disaster.

Community engagement takes more than one form such as groups of coordinated volunteers, the general participation of locally affected persons, and time-donating dispersed volunteers who are not directly affected. This is particularly important when it comes to the connection between crisis maps and social media information. During the earthquake the Twitter hashtag #eqnz, alongside competing hashtags such as #nzquake and #christchurch, were widely used (Beatson, 2016). The use of hashtags in social media created a point of communication that could be used in Christchurch and New Zealand, and across the world. This communication created a two-sided system: a dialogue for individuals to talk about the event, and also a source of information for affected persons/EMOs to gain situational awareness. In the case of the Christchurch crisis map, social media created a direct link to notify the crisis map administrators of important issues or developments. This link through social media complemented the use of SMS communication and direct contact with the EQNZ website (Beatson, 2016). An important note around this observation was the need for a volunteer base to process this information, with much of the processing being done by volunteers in Wellington, New Zealand. Yin et al. (2012) discuss this in a post event study implementing a Twitter monitoring system that filters based on the use of keywords. The output of their investigation are visualisations of geotagged data that show issues of importance by volume. Although arguments can be made around methods of data collection and the impact it has on different groups (particularly those with restricted access to technology), this form of collection is a good case study for the integration of indirect information into crisis map systems.

A study of social media in disaster response was also undertaken by Glenerter and Mushegian (2011) using Christchurch as a case study. Rather than looking at this from the perspective of community engagement, they examined the nature of how people communicate and how that relates to difficulties in taking bulk data to form situational awareness. This work also looked at location analysis when the crowdsourcing is without geo-tagging. Across this research it was identified that existing software available for text analysis, specifically the Stanford's NER (Name Entity Recognition) software, can have issues with syntax. Changes in capitalisation, use of improperly placed symbols, or misspelling of words, can have an impact on automatic identification of samples. This is a factor for consideration of any proposed system of social

media data information into a crisis map. Secondly the research examined the capability to find the physical location of reference in a given social media post. This is done through analysis of location-referring words in tweets to narrow down a location. Geo-parsing, as it is called, can yield its own crisis maps of Twitter message locations. These data however are recognised as having high variability in quality and the question of its application in a live situation needs further investigation. Glenerter and Mushegian (2011) highlight the technical hurdle agencies will face in trying to integrate crowdsourced data.

When establishing any map which will be used by people in critical situations, the quality of data is of the utmost importance (Glenerter and Mushegian, 2011). As discussed earlier in this literature review, methods of quality assessment vary but all ultimately aim to achieve the same goal; verification of crowdsourced data. Beatson (2016) addressed this in the context of the Christchurch earthquake. To paraphrase, verification is a complex task that involves investigating (moderating) volunteered information for usability. As such the verification procedure was actually undertaken remotely in Wellington through 'face-to-face collaboration' and aided by training from experienced members of the volunteer team. Applicable lessons from this verification process included the importance of proper training and accountability procedures, in this case user identifications and password-protected moderation systems. Using the shared workspace in Ushahidi software, inbound information flows could be moderated for publishable suitability. Beatson (2016) wrote positively about the act of verification as it allows for a "flexible, self-directed, and synchronized….division of tasks" that aids the process of getting information out to the public. Beaton (2016) also remarked however that further research is needed on the ability of labour intensive moderating processes to scale with information surges during a disaster cycle, while maintaining the quality seen in this volunteer group's work.

For the discussion around elements of a crisis map there is one final question, and arguably the most important: Is it effective? This question posed for crisis maps in this form has significance as it is the primary example in New Zealand of using CGI to try to address and ease the harm caused by disasters. Across Beatson's (2016) work the question is consistently redirected to this idea of can it be used, and how it can help? To this extent Beatson (2016) found that crisis maps have been effective for response in the 2011 Christchurch earthquake. The output of crisis maps has improved situational awareness improved planning and response.

2.3.2. Interagency adoption of Crowdsourced Geographic Information and community cooperation

Data from crowdsourcing creates new possibilities for responding to the negative impacts of disasters, and while this is the subject of academic research and debate it is a logical conclusion that data without systems to translate it into meaningful action is meaningless information. To that end this section addresses whether crowdsourced data can benefit New Zealand disaster response through response agencies engaging with the data. In addition, the degree to which agencies share data amongst themselves and the communities impacted by a disaster will also be addressed.

Dantas and Seville (2006) investigated the issues associated with implementing information sharing networks from an organisational perspective. Information sharing in this instance is the formal infrastructure for data sharing in an effective and timely manner. Dantas and Seville (2006) use another New Zealand disaster event, the 2005 Matata flooding event. This event was characterised partially by considerable interference/damage to public roading infrastructure, and the paper was written from a public roading agency viewpoint. Dantas and Seville (2006) concluded that interactions between the agencies involved created a need for an 'intra organisation data sharing' network. Specifically, during the disaster two agencies (Transit NZ – transport infrastructure; and Telecom – a telecommunications company) experienced very different periods between the disaster occurring and having a situational overview of the damage done to their networks. Transit NZ local consultants were activated to assess road damage, and did so through reports from the public and a helicopter survey that combined created a situational overview more than 12 hours after the initial weather reports. In comparison, Telecom through their Road Assessment Maintenance Management (RAMM) system used technological sensors to identify points of network damage. The result of this was a full restoration of Telecom's network within a few hours of the disaster. Dantas and Seville (2006) argued that if Transit NZ had access to the RAMM network they would have had almost immediate situational awareness and could have started restoring roads before the disaster had finished its course. This finding raises an interesting question around what technologies disaster response agencies currently use and if these are shared for mutual benefit.

Beyond government-mandated and professional response organisations exist volunteer community groups. Beatson (2016) refers to these as 'emergent citizen groups' and takes a definition from Stallings and Quarantelli (1985: 94):

> [citizen emergent groups are] groups that can be thought of as private citizens who work together in pursuit of collective goals relevant to actual or potential disasters but whose organization has not yet become institutionalized … Such groups are considered emergent in two respects: the relationship among the individuals pursuing the collective goals is new (the group has an internal structure that did not exist before) and the tasks being undertaken in pursuit of these goals are new for individuals so joined. In its purest form an emergent group has a new structure (i.e., social relations) and a new function (i.e., goals and tasks).

These groups were identified in the Christchurch case study. Specifically the team who produced the Christchurch Recovery Map, while involving open source professionals, were a previously unformed group who came together as citizens working for a common goal. This definition also extends to local level community groups that form in a post disaster environment, providing food, shelter and, significant to this investigation, information, to the public (Beatson, 2016). These groups and their interaction with official agencies will change the degree to which their outputs, such as crisis maps, will be shared and adopted.

The interaction between official agencies and the community overseas has been discussed by Beatson (2016). Beatson references Okolloh (2009) and Morrow et al. (2011), using the disasters of the Kenyan 2008 election and the Haitian earthquake respectively. In the Kenyan example there was a distinct hesitation by formalised agencies to adopt and trust this emergent form of data. Specifically the NGOs that were invited to map the civil unrest "[did] not appear to want to embrace this form of citizen reporting [an established Ushahidi map]" (Okolloh 2009: 69). In contrast to this Morrow et al. (2011) concluded in their examination of the Haiti earthquake (that used the same platform and system) that there was "concrete and convincing evidence of official emergency management organisations finding value in the data produced by this emergent deployment to support the 'situational awareness for strategic, operational and tactical organizations'" (Morrow et al. 2011, from Beatson, 2016). The situation in New Zealand during the Christchurch earthquake appears to exhibit elements from these contrasting examples.

When the Christchurch Recovery Map was implemented it featured cooperation from both volunteers, the private sector, and academic institutions. Primarily a volunteer-run initiative, telecommunication companies including Telecom, Vodafone, and 2 Degrees provided support

with phone communications. This enabled volunteers to communicate at distance easily which was of particular importance as a large part of the volunteer workforce was based in Wellington from the Victoria University of Wellington (VUW). VUW provided rooms for volunteers to meet, work and organise to produce this map. This support from private and academic institutions did not however mitigate the concerns around applying a volunteer crisis map. Concerns primarily related to what information was coming from central agencies such as Civil Defence, and what was from the general public (with implication that public data had inaccuracies). Beatson (2016) noted that an attempt was made to differentiate and understand this information however was not done within the time frame of the event. This has implications for future crisis maps, as without support and implementation crisis maps cannot be effective.

This contention between volunteer organisations and the formal response agencies centres on the structure of response called the Coordinated Incident Management System (CIMS). This system is the physical and software systems that exist to allow agencies to coordinate their resources. Beatson (2016) and a report by McLean et al. (2012) noted that what is absent from this system is a method of liaising with volunteer organisations, or at least groups that develop in response to a disaster. Of significance is that in McLean's (2012) report one of the major findings was that "new structures be developed to modify CIMS so as to better link the response to emergencies with the community and community organisations" (McLean et al. 2012: 202). A positive drawn from this is that the Ministry of Civil Defence Emergency Management (MCDEM) released a corrective action report (MCDEM 2012) which agreed with this conclusion. Community groups do not exist in isolation, and often experience direct interactions with traditional response agencies.

Civil Defence, in this instance, was generally supportive of volunteers producing a product for public good. Particularly as it was directly supported by a reputable academic organisation. However contention for the project centred on what data was used in the final product. This implies that the data from people at ground level, the public and community groups, was not accepted or at least not utilised formally in 2011. The outcomes of these interactions are of critical importance for future applications of crowdsourced data, because community groups are a primary source of human labour and data collection.

2.4 Summary

The main considerations for this thesis from this literature review are the following:

- Crowdsourced Geographic Information represents a form of data that is both emerging and has the potent to change how we look at data collection as professionals.
- Disaster response requires up-to-date information as responders make decisions based of damage caused and its impact to populations.
- Crowdsourced Geographic Information in disaster response has its roots in Ushahidi, a form of CGI that started in Kenya to help people communicate during a period of civil unrest.
- Crowdsourced Geographic Information in disaster response can be direct and indirect:
    - Direct: legacy datasets (OpenStreetMap) and response datasets (TomNod satellite image viewing effort).
    - Indirect: Social media collection.
- Lessons from international case studies:
    - Crowdsourced Geographic Information efforts can both aid local governmental response and can be in conflict with this.
    - People have an incredible capacity to contribute and this has been capitalised by some crowdsourced projects, particularly OpenStreetMap with their HOT initiative.
    - Local spatial information tends to improve after a disaster.
    - Distance of volunteers from a particular incident has minimal impact with many crowdsourcers using remote information (typically imagery) to produce data. This however is not the case for CGI on population/welfare impacts, which still need to come from those affected on the ground.
- New Zealand studies are limited and have focused on specific events/responses.
    - There is a need for a study from a wider perspective that looks at how crowdsourcing could be used across the entire response system.
- In New Zealand the primary application of crowdsourcing was through three crisis maps developed during the 2011 Christchurch earthquakes. Lessons from this can be applied to this thesis research.

Chapter 3 – Methodology

3 Methodology overview

The methodology focuses on thematic analysis of interviews with key informants from a selection of New Zealand's disaster relief organisations. To create the method outlined below, three primary texts were used for reference: The SAGE Encyclopaedia of Social Science Research Methods (Lewis-Beck et al, 2004); Qualitative Research Practice – A guide for Social Science students and researchers (Ritchie and Lewis, 2003); and Qualitative Research Methods for Social Sciences, 5e (Berg, 2004).

The research in this thesis follows the responses of key informants as they discuss their involvement (from a GIS perspective) in disaster response. These responses are shaped by a series of questions designed to address the research topic of "*How can Crowdsourced Geographic Information be utilised to the benefit of New Zealand governmental and other agencies' responses to disasters?"* The questions (presented in appendix A) provided the framework for semi-structured interviews addressing these topics:

- The organisation's involvement in disaster response operations.
- How the organisation uses GIS and spatial data in disaster response.
- The informants' experience around the use of CGI.
- The informants' ideas as to how crowdsourced data might be used in the future.

With information from these topics, thematic analysis was conducted to develop an understanding of how CGI can be used in New Zealand.

3.1. Interview design

The interviews themselves are designed around the principles outlined in the SAGE encyclopaedia (Lewis-Beck et al, 2004) and Ritchie and Lewis's (2003) chapter on in-depth interviews. There are three primary methods of interviewing subjects in social science: structured, unstructured, and semi-structured interviews.

Structured interviews use a rigid set of questions, accompanied by a set of instructions for the interviewer on how best to pose questions that are designed to have specific answers. The goal of these questions is to get definitive answers to queries that have little variation in phasing of response. Generally, structured interviews are used for research questions that will use statistical analysis of respondents' answers; political polls would fall into this category. In structured interviews, direct questions are needed to remove ambiguity in results. However for much of social science research, this is not applicable as the questions posed are more nuanced and look to provide data that leads to new understandings.

Unstructured interviews often use a respondent-led approach that employs open-ended questions to collect as much information as possible. This type of interview is used either to help develop a question by asking something like "what issues are important to your community," or to collect stories and experiences as part of narrative study. With both structured and unstructured approaches there are benefits and drawbacks. Structured interviews collect good data around a specific question, while unstructured interviews allow for discovery and can address questions around experience and perception.

The dichotomy between structured and unstructured interviews makes neither approach suitable for answering the question of the experience around using a particular type of data such as CGI. A solution to this is to use semi-structured interviews. As described by Lewis-Beck et al. (2004), a semi-structured interview focuses around a series of topics or points to be covered. However, the way in which the questions for these topics are asked is left for the interviewer to decide. Additionally, a provision is made in semi-structured interviews for both open ended questions that can discover previously unconsidered topics, and impromptu questions that elaborate on these topics. Importantly, the semi-structured interview process allows for iterative exploration of ideas that emerge as the data collection proceeds. Accordingly, semi-structured interviews were conducted for this research, based on the set of questions provided in Appendix A.

3.2. Participant Recruitment

Interview participants were recruited from three organisations: Geospatial Intelligence New Zealand (GNZ), an arm of the New Zealand Defence Force (NZDF); representatives from Canterbury Civil Defence and Emergency Management (CCDEM) and Emergency Management Otago; the New Zealand Red Cross (NZRC); and South Island iwi Ngāi Tahu.

These organisations provide primary response to disasters that are of interest to New Zealand, both domestically, and in the Pacific region. While there are a variety of other agencies that respond to disasters, the above organisations were selected because they contribute to the planning and intelligence operations that concern the use of geographic information; in the case of Ngāi Tahu, they have extensive experience in engaging with communities during and after the 2010-2011 Canterbury Earthquake Sequence. The participants were invited based on the following criteria; direct involvement in some aspect of disaster response; direct involvement into GIS data collection and analysis; manage teams that create spatial intelligence; and input into organisational strategy concerning the use of crowdsourced data.

Once candidate organisations and personnel within them were identified, they were approached initially to determine their willingness to participate in this research. When positive assent was gained, a formal procedure was initiated through the University of Canterbury Human Ethics Committee and the University of Canterbury Ngāi Tahu Research Centre to have the proposed research vetted for appropriateness, and to ensure participant confidentiality. Please see Appendix C and D, respectively, for the University of Canterbury Human Ethics Committee and Ngāi Tahu Research Centre approval letters.

3.3. Thematic Analysis

The information gained from semi-structured interviews was then subjected to thematic analysis. As described by the SAGE encyclopaedia (Lewis-Beck et al, 2004), thematic analysis is the process of finding themes and sub-themes within responses made by research participants. These responses are to questions and prompts from an interviewer as a research question is explored. The outcome of this exploration was themes and sub-themes that provide a higher level of understanding than the participants were able to generate as individuals. There are two types of thematic analysis; context and narrative (Lewis-Beck et al., 2004). Contextual analysis looks at a body of text to understand the core themes that define its perspective. Narrative analysis looks at analysing a range of participants for common linking themes. This study used both as it attempted to understand how each organisation deals with the issue of crowdsourced data, while also piecing together what New Zealand's disaster operations' perspectives on this data are. The key topics through the interviews are:

- What the organisation's involvements in disaster response operations were (with a focus on GIS contribution);

- how they used GIS and spatial data for disaster response;
- what their experience working with crowdsourced data has been;
- what future user-potential applications do the informants foresaw.

These four topics generated an understanding of the current and potential use of crowdsourced data use in the New Zealand disaster response arena.

3.4. Result structure

The interviews conducted during this thesis, being in-depth and from authoritative sources, need to be documented as a series of answers to specific questions/topics. This is to say that the contribution from each participant is very important and needs to have their viewpoints on each question noted. This forms a base layer of information for the reader to understand how the participants view elements of the question of 'how crowdsourced data can be used in disaster response work'. Further to this is a record of the different themes participants presented in their interviews. These individual response results form Part One: Participant Interviews and Responses. Part Two: Organisational Perspectives, collates this data by the organisation each interviewee represents. This will enable the grouping of themes consistent across respondents and the selection of remarks referring to this issue from an organisational viewpoint.

Chapter 4 – Key Findings

The key findings from interviewing New Zealand disaster response agencies, and Ngāi Tahu, are presented below. Also presented are figures showing the flows of data and information between agencies and organisations based upon this research and the literature.

4.1 Data flows between agencies, and types of data used

Figure 2 outlines how information flows for national level response organisations work. The black lines represent organisational hierarchy, while the yellow lines represent disaster event specific information flows. At a macro level, this diagram represents how information is collected from ground level, and is disseminated up from local to national headquarters to be analysed, and then re-disseminated back down to response workers in the form of situation reports. Important elements to note include; a strong association between NZRC and CDEM that persists at all levels; NZDF to CDEM engagement being conducted at an HQ level; Red Cross to NZDF engagement happening with CDEM as an intermediary through CDEM generated situation reports; and all of the flows are framed with Reduction and Readiness being more heavily engaged with by HQ level branches, with Response and Recovery being of greater concern to local branches and first responders.

Figure 3 expands on Figure 2 by identifying each source of the information flow and how each agency uses this in relation to reduction, readiness, response and recovery. Figure 3 shows non-crowdsourced (or traditional) sources of data. The trends this figure are; data collection is primary focused on response efforts with the readiness and recovery efforts next more frequent; CDEM and NZDF are large consumers of all information (connected to their national mandate to manage events on behalf of the government), while Red Cross consumes more ‘active’ information that is event specific. Beyond the process depicted in this diagram, reduction and readiness efforts use data developed over a long period, including private data acquisition and analysis from this informing response plans; response information has a more widespread approach of taking information from almost any and every source; Red Cross engages, at an information level, with more response based work and uses internal/EOC information to inform its decision making processes.

Figure 4 shows how these agencies have dealt with crowdsourced data up to the present and where future sources are planned. Again, there is a clear differentiation between reduction to readiness, and response to recovery stages, with the latter being significantly more information heavy. Crowdsourced data from the interviews was categorised as, part of an organisations' policy (P), policy but infrequent (I) and developed future plans (F). Within these categories, social media and public-agency communication form the bulk of this information, and are clearly a well-developed source at this time. A greater focus on crowdsourced data for recovery as opposed to non-crowdsourced data; OpenStreetMap is not heavily used in New Zealand and even for NZDF this is primarily an overseas activity; at present only one agency has a developed strategy to use a crowdsourcing campaign where the public contributes directly.

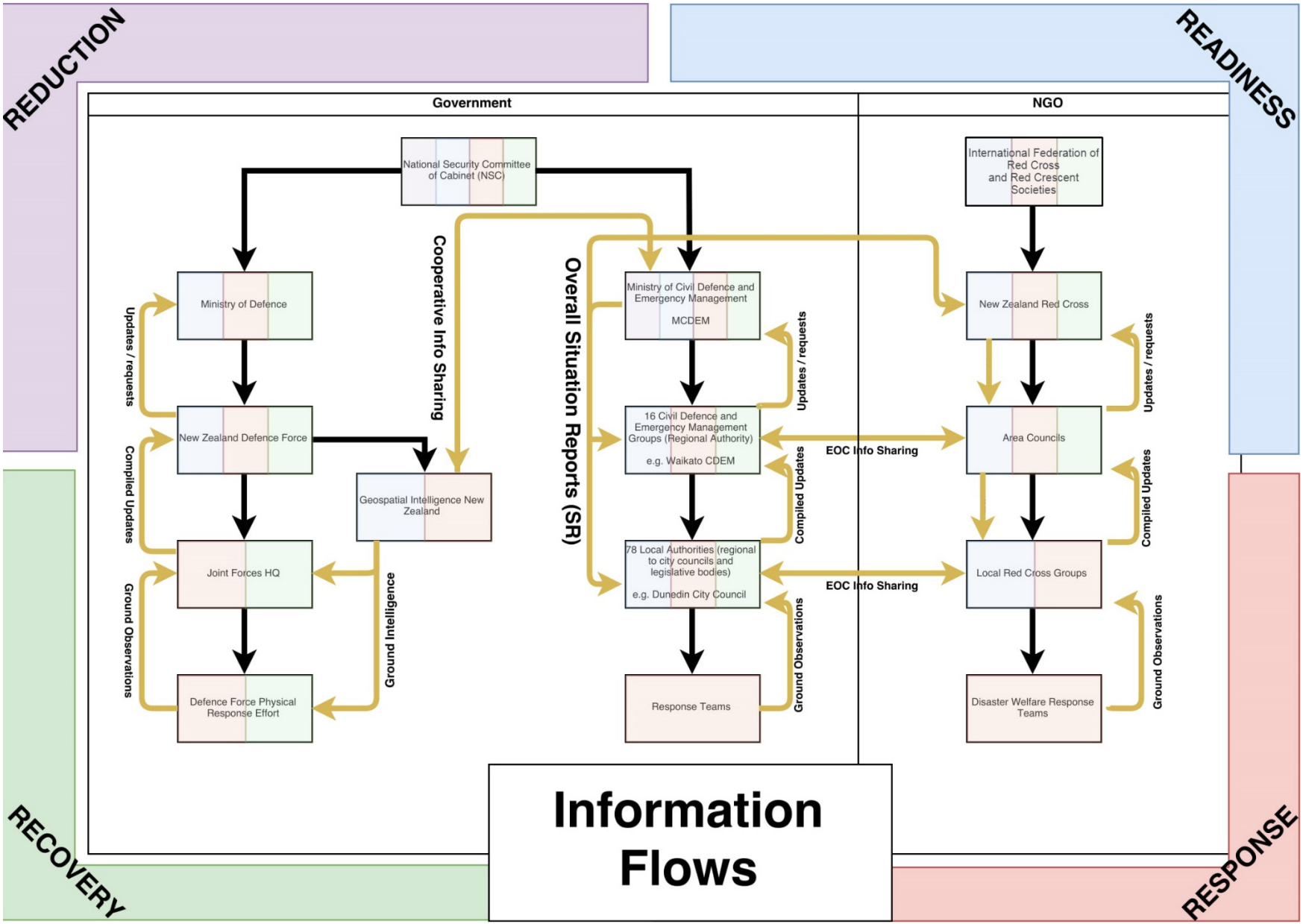

Figure 2. Information flows between New Zealand disaster response agencies, classified based on their use in the Fours Rs.

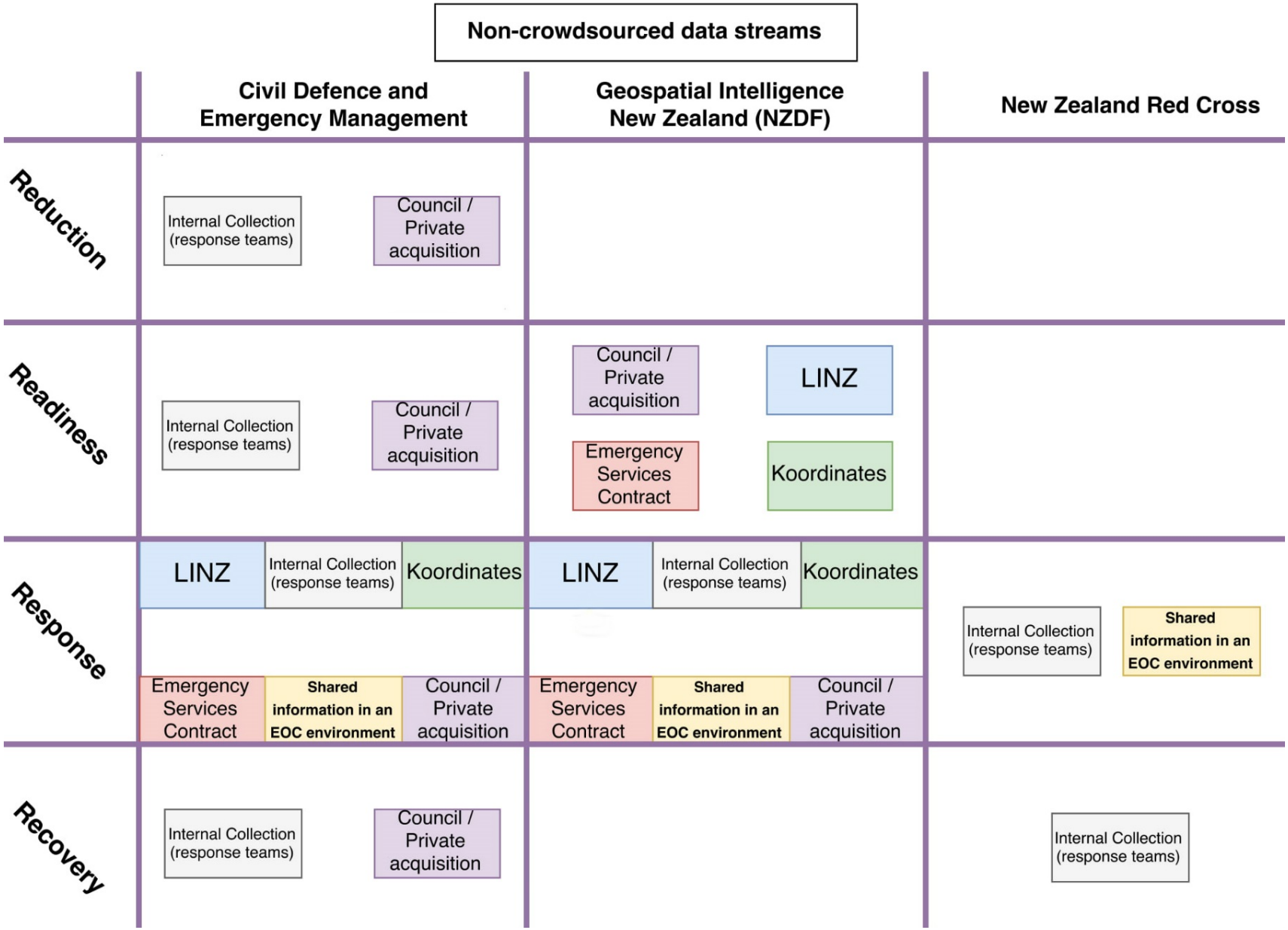

Figure 3. Non-crowdsourced data streams used by New Zealand disaster response agencies, classified by the Four Rs.

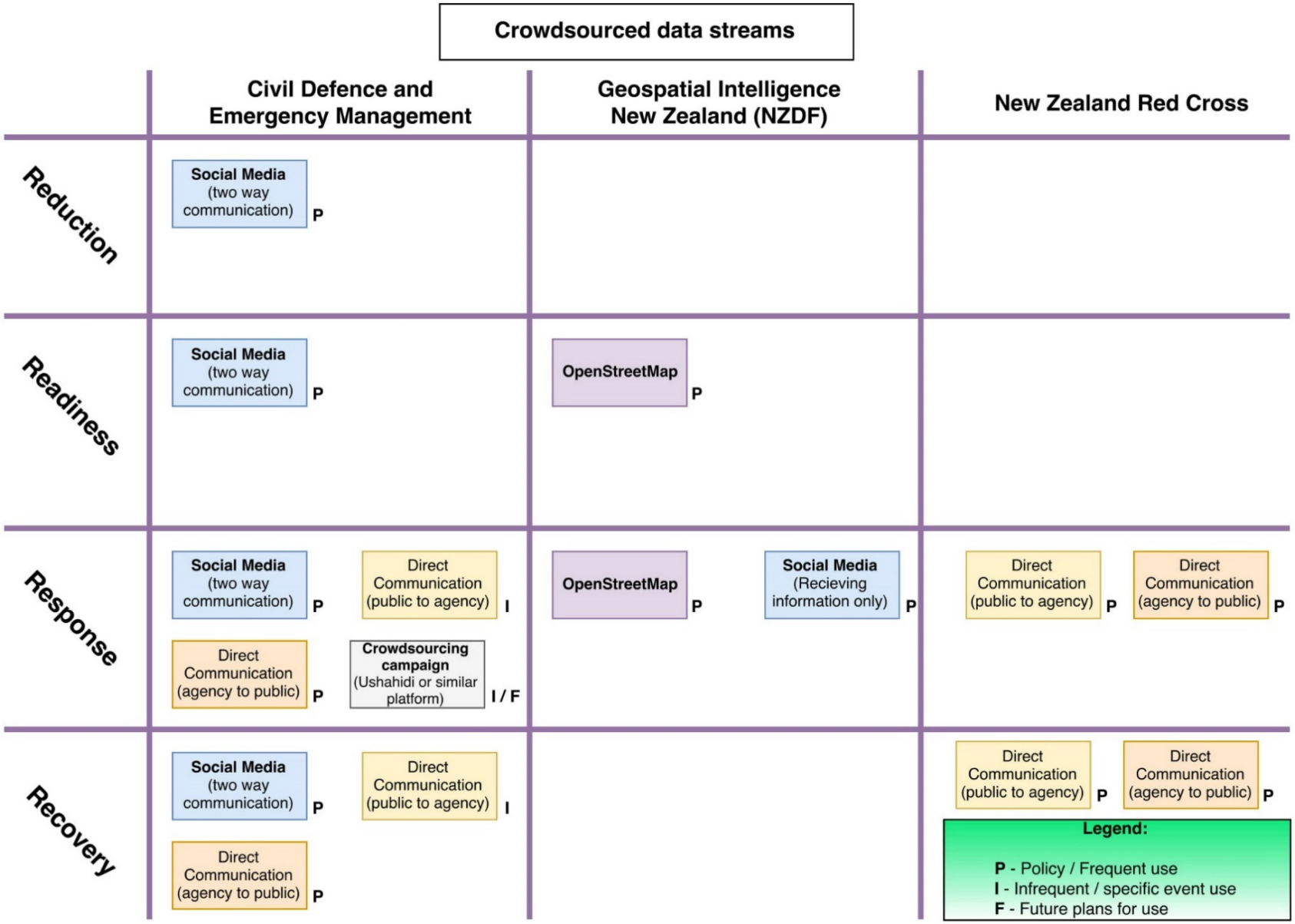

Figure 4. Crowdsourced data streams used by New Zealand disaster response agencies, classified by the Four Rs.

4.2 Interview Question Summaries (By Organisation)

As the questions given to the participants (3.1.2.) were designed to create a flow of dialogue, this section breaks down the extensive questionnaire into six (6) key points which summarise each organisation's views:

1. **Function:**
   What function does their agency have in relation to New Zealand disaster response operations, i.e. their scope, and level of technical GIS work?
2. **Information Use:**
   What information is used by the agency; what are the limitations of this information; and what do they value most in information used for disaster response?
3. **Crowdsourcing:**
   How does the organisation define crowdsourcing, and how does crowdsourcing currently fit into operations?
4. **Limitations:**
   From their understanding of crowdsourced data, did the interviewees perceive any flaws or limitations of crowdsourced data?
5. **Future Plans:**
   What is the future direction of the interviewees' agency regarding information collection for disaster response?
6. **Relationships:**
   How do the interviewees view the relationship between their agency and external volunteer groups regarding the handling of data for disaster response?

4.2.1. Civil Defence Emergency Management Interview Summary

1. Function:
   Civil Defence Emergency Management is a government organisation which acts under the Ministry of Civil Defence and Emergency Management. As such, CDEM is the primary responder to disasters at all levels, from national emergencies involving Cabinet and the Prime Minister's Office, to regional and local events which employ CDEM in EOCs near the event site. CDEM is involved from strategic planning to ground level implementation working alongside other agencies. From a technical GIS

standpoint, CDEM uses the ESRI suite with an increasing focus on online portals.

2. Information Use:

   As noted in Figure 3, CDEM uses different sources of information at each different stage of the disaster response cycle. CDEM's Reduction and Readiness efforts are directed towards understanding the risks posed to people before an event takes place. Due to this focus, much of the information is technical in nature, and examines risk factors such as population demographics, local topography, and models of event impact. This information is used to create a picture of how an event could impact people. Supplementing this information is a form of crowdsourcing from social media (see *3.Crowdsourcing*). During the Response and Recovery stages of the Disaster Management Cycle CDEM takes their predictions of impact and tries to assess the actual impact of an event. This stage uses data from 'anywhere we can get it', a common phrase noted in the interviews. This expresses the chaotic and fast paced nature of events which require CDEM to search for information wherever it may be available. Any information collected – whether from emergency services, active observations, other EOC participants, or even from social media (see *3.Crowdsourcing*) – is then combined to help create a dynamic picture of the current ground situation.

   Information collected, regardless of its source, is valued for both its integrity and quality, as well as the temporal relevance of the data. Most forms of data used by CDEM, particularly during the Reduction and Readiness stages, have a high degree of trust while simultaneously lacking in temporal relevance within an event timescale. Some sources, such as the Emergency Services Contact's (the internal information sharing network of emergency services) and direct response team observations serve to bridge this disparity, but as the adage is 'anywhere we can get it,' more sources with temporal relevance are desired for their positive impact on decision making.

3. Crowdsourcing:

   CDEM respondents defined crowdsourcing as an effort to collect information from the public to help create a better understanding of a situation. This definition relates to CDEM's main current source of crowdsourced data; directly volunteered reports (through local/regional Council call centres) and social media observations (conducted by intelligence teams in an EOC). These forms of crowdsourcing have proven very

effective at creating situational awareness, but are recognised in their current form to have limitations (see point 4).

Emergency Management Southland is unique among CDEM participants as they have developed and are testing a crowdsourced application. This application is a direct crowdsourcing platform which will enable members of the public to send reports directly to the Council which can be reported (at the Council's discretion) back to a publicly viewable web map. Early tests have been positive, however while the data collected has met their needs as a response agency, the costs of implementation were a considerable and limiting factor (see *4. Limitations*).

4. Limitations:

   All participants showed a good understanding of crowdsourcing while likely viewing this from mainly a data collection standpoint (as opposed to data processing). From this viewpoint, and in a general sense, crowdsourcing was met with concerns such as reliability/trustworthiness, along with apprehension with regard to the challenges of how to implement a crowdsourced system. To the first, CDEM participants expressed that with direct reporting by the public, particularly related to incident/damage reports, a lack of expertise can prevent information being taken at face value and resources being expended to follow up and confirm these reports. To the second, a considerable concern raised was that local and Regional CDEM organisations lack the necessary funding to implement a comprehensive data collection system and the associated awareness campaign. The general consensus is that, for a crowdsourcing system to be used at the extent CDEM would like, the system needs to be implemented at a national level. This is a sentiment also shared by Emergency Management Southland acknowledged the high cost of running a crowdsourced platform.

5. Future Plans:

   Amongst CDEM leadership there has been a recognition of the need for data which can react to changes of the situation on the ground during an event. This has led to discussions around how crowdsourced data can be used to achieve this. The general view is that crowdsourcing will take a role within every future event in some capacity. Details of how crowdsourcing will be implemented are largely unknown and opinions vary between respondents as it was largely speculation. However, some more definitive

plans are known; active discussions at a national level are taking place regarding how crowdsourced data can be used; a test crowdsourced system is being implemented to help inform this discussion; and all participants agree that whatever system is implemented will likely be standardised and of a national scale.

6. Relationships:

   A consensus was reached between the various interviewees regarding engagement with crowdsourcing groups; there hasn't been any significant involvement to date. This was noted to not be a product of a disinterest, but instead a more incidental impact of CDEM still 'maturing' in their understanding of crowdsourcing as one participant opined. From a future perspective, this engagement is desired, but no notable action plan has been formed for how to find and engage crowdsourcing groups.

4.2.2. New Zealand Defence Force via Geospatial Intelligence New Zealand

1. Function:

   The New Zealand Defence Force acts on behalf of the government in support of CDEM. This includes a direct response from the different branches of the military under Joint Forces HQ which can provide logistical, intelligence, and physical support. Within the NZDF, Geospatial Intelligence New Zealand (GNZ) operates as the intelligence arm. As such, GNZ provides the most accurate representation of how geospatial data is used to engage with events, and therefore any potential use of crowdsourcing. The scope of their work ranges from domestic to international aid operations, and is primarily from a logistical perspective. At a technical level, GNZ uses standard GIS technology (ESRI products) also used by Civil Defence, as well as remote sensing image analysis software. However much of this is done within a secure data environment where outside collaboration can be challenging.

2. Information Use:

   GNZ, working from a logistical focus, uses primarily a combination of government, private and internal data for creating appropriate maps for event response. This leaves little room for crowdsourced data in much of their preparation work which involves updating existing maps for response. While this is the case, there are two distinct

exceptions; international operations making use of OpenStreetMap; and an increasing view towards implementing crowdsourcing to supplement response maps in order to enhance logistical decision making.

3. Crowdsourcing:

   GNZ defines crowdsourcing as an environment where people can provide spatial information, or in the words of one participant, “an environment where the general public can contribute to a geospatial picture.” This view is one of direct data contribution, again focusing on what people can tell response agencies, as with CDEM’s views. Direct contribution aligns well with GNZ’s focuses on logistical support overseas, especially in events being aided significantly by the presence of OpenStreetMap. In these instances, participants informed me that OpenStreetMap has been an excellent source of information in countries where infrastructure data is not as up-to-date as in New Zealand.

4. Limitations:

   When asked about flaws and limitations of crowdsourced data, GNZ participants noted two things. The first, a view shared by some participants from CDEM, is that crowdsourced data represents something new that is going to take time to implement into existing work. Notably, one GNZ member explained that the lack of a ‘single author control’ for crowdsourced data means that a level of learning is needed to understand how it can be used and if additional work, like verification, is needed to comfortably implement this data. Secondly, relating back to the role NZDF takes in events, more specific crowdsourced data, such as incident reports, are not a concern. The reasoning given for this is that a logistical focus requires a wider scope and is more concerned with datasets such as roads and bridges; crowdsourcing to-date in this area has proven to be very effective, and they cite OpenStreetMap in this.

5. Future Plans:

   The future of crowdsourced data in New Zealand was one topic that GNZ participants spoke positively about in two contexts; applications for GNZ, and how crowdsourcing advances GIScience in general. Regarding its applications for GNZ, this is dependent on what is required of the organisation in the future. GNZ as an agency of the NZDF – and through that, Government – is directed as to where their efforts are to be used, but

using their current primary function of logistical intelligence support, crowdsourcing can be a powerful tool, even domestically. Participants from GNZ noted that a robust crowdsourcing platform that can collate information regarding changes to infrastructure during an event would be useful for this response agency. From a more generalized perspective, participants held the belief that crowdsourcing will be a critical component of GIScience in the future. To this end, some respondents emphasised the need for all disaster response agencies to become familiar with crowdsourcing theory, as it is predicted by GNZ participants that this type of data will become a major component of future data collection.

6. Relationships:

   At the time of writing, there has been no engagement between GNZ and volunteer crowdsourcing organisations despite considerable involvement with formal response agencies. This is attributed to current activities and the limited use of crowdsourced data to-date. When asked if this position would possibly change, the response was positive. It was said by participants that, as crowdsourcing becomes more prevalent, there will be a need for direct engagement with groups outside of a normal CIMS environment, at least to the extent those groups are involved with the data that GNZ uses for its response work.

4.2.3. New Zealand Red Cross

1. Function:

   The New Zealand Red Cross, “has a number of guiding principles, but it is all based in the mission to improve the lives of vulnerable people, and mobilise the power of humanity. As part of that, we have arrangements with the [New Zealand] Government through our auxiliary status as a provider of support during a disaster; something which we have a remit to do internationally as Red Cross”. This status puts NZRC in a response provider position within CIMS. NZRC is primarily a response team provider through their Disaster Welfare Support Teams (DWST). From a GIS perspective, this means that there is limited engagement with processing spatial data, but NZRC acts as data collectors through their response teams. Importantly, it should be noted that DWST teams have a strong and direct connection with the public during an event.

2. Information Use:

   Information used by NZRC comes from CDEM situation reports, along with an internal intelligence process from response team observations. It is through these DWST observations that some interesting insights have been gained. NZRC notes that their 'door knocking' activities generate much of the crucial decision making information, as it is unfiltered and reflects any suffering that people in an event are experiencing. This information is also fed back into CIMS, which means the situation reports and observations are intrinsically connected.

3. Crowdsourcing:

   The participant explained that crowdsourcing is not focused on by NZRC. Its fit within NZRC operations is incidental and primarily seen in incident reports informed by social media.

4. Limitations:

   A strong reasoning for this lack of use is the focus on the most vulnerable; they explained that NZRC, by its mandate, are to take care of the most vulnerable. To do this, NZRC must focus on those who are in areas impacted (found through situation reports), and those who are most likely to be impacted, i.e. the most vulnerable. Because of this mandate, the participant raised a conundrum in that those most vulnerable are also those least likely to have access to the technology CGI is based. Essentially those who would most benefit from this technology are the least likely to have access to it. Further, regardless of socio-economic circumstance, in an event some areas will lose communication infrastructure thereby preventing CGI collection.

5. Future Plans:

   NZRC does not have intentions to access crowdsourced data in the future, and instead has increased efforts to better collect and understand impacted people through response team technology. This is done through a system called MagPi. MagPi is a mobile survey platform that is used in door-to-door checks of properties that connect the information spatially with a central GIS system (usually operated in conjunction with an EOC). While this system isn't explicitly crowdsourcing as it is still being collected/filtered by a trained professional, it acts as a direct method of communication for vulnerable people.

6. Relationships:

   Of all the groups interviewed, with the exception of Ngāi Tahu, NZRC has the closest connection to community and volunteer groups with much of the people working under NZRC being volunteers themselves. It remains to be seen however for crowdsourcing groups to engage with NZRC, but the participant did recognise that groups looking to help those who are vulnerable will have a positive relationship with NZRC.

4.2.4. Ngāi Tahu

1. Function:

   Ngāi Tahu was a statutory partner in the recovery of the 2011 Christchurch Earthquake alongside the three local TAs impacted, with all four entities lead by CERA (Christchurch Earthquake Recovery Authority). This position made Ngāi Tahu, a New Zealand indigenous iwi, responsible for elements of response to this event. To this end, Ngāi Tahu assisted response and recovery through community support and direct intervention with grants/aid. From a technical perspective, Ngāi Tahu has an internal GIS team which allowed for monitoring of their iwi members during the event.

2. Information Use:

   Ngāi Tahu uses publicly available information as part of its GIS, as well as internal information about iwi members. At present, it is estimated that around 10% of the Ngāi Tahu population is recorded on their GIS, and this was used extensively during the event to assist in rendering aid.

3. Crowdsourcing:

   Similarly to NZRC, Ngāi Tahu has not focused specifically on crowdsourcing, but instead on methods of direct communication and providing aid to their community. This perspective, as well as that of working incredibly closely with a community devastated by an event, provides some useful insights into the benefit of close engagement with the public, a principle of crowdsourcing.

4. Limitations:

   The organisational background, and the viewpoint generated, is shared by NZRC. The viewpoint is that crowdsourcing is a tool of the public, and for that tool to be controlled

by a central agency could be a mistake. Ngāi Tahu expressed that, for widespread collection of public information to be performed directly by the government, it could become biased and not serve to help those most in need. The view of Ngāi Tahu is that crowdsourced data needs to be unfiltered, and not bracketed into specific questions, in order to provide the most realistic view of what the needs of impacted peoples are. Crowdsourcing in Ngāi Tahu's view should be driven by the public.

5. Future Plans:

   There are no future plans for engagement with crowdsourcing in disaster response.

6. Relationships:

   Ngāi Tahu, in the opinion of its representative, has excellent levels of engagement with the outside community. They view this level of success as a result of their own system; Joint Action Groups (JAG). JAGs were an organisation tool used to connect Ngāi Tahu to volunteer groups to facilitate response work. This model of leadership involved both planning and direct community engagement. JAGs functioned through community meetings and *kaitoko* (field surveyors) to create this model of response. The participant suggested that crowdsource planning could benefit from implementation of a community focused approach.

4.3 Thematic Analysis

Presented below are thematic analyses of the key research questions. These have been developed using the methods described in Chapter 2, and summarise key concepts and views held by the interview participants concerning CGI. These analyses will be used to inform discussion in Chapter 5 along with recommendations.

4.3.1 Universal Themes

- Advocating for the value of crowdsourcing
    - All participants agree that crowdsourcing can add valuable information to disaster response operations, the degree to which this is true varies however all (with the exception of Rik Tau) see crowdsourced data as a significant part of future disaster response operations
- Social media primary method of crowdsourcing
    - CDEM, GNZ, and NZRC all use social media as a major form of crowdsourcing. For CDEM it is the primary way of finding out publicly generated information and for GNZ and NZRC it represents as way to gain situational awareness.
- Need for information about people in need
    - Foundational information is generally available to the agencies, either through LINZ and government or through the Emergency Services Contract that is regularly updating to provide the most relevant information. This data however does not address the issue of who is in need after a natural event.
- Crowdsourcing supplements existing information
    - As with the example of social media, these agencies view crowdsourced data as a supplementary source that can inform decisions and either provide indication of areas needing further investigation or potentially confirm reports or suspicions of people and places in need.
- Crowdsourcing not a universal solution
    - Crowdsourcing is considered valuable however as noted by all participants is not the end solution to disaster response information. Much of the valuable information collected comes from analysis and reports from professionals in the field. Crowdsourcing can supplement this but not replace it.
- Phases of a disaster need different information

- A theme amongst the participants was how different phases require different approaches, and therefore different datasets to understand the current situation. Notably it was discovered that CDEM operates over all 4 phases, while NZRC acts as a response agency and then community recovery support, and GNZ acting as an arm of the NZDF is primarily dealing with response efforts and contributing to some aspects of readiness, in the form of supplying data from defence assets.

- Crowdsourcing best not used in isolation
  - The participants noted the inherent issues with using data that does not come from professional bodies with associated standards providing a form of quality control over their data. As such crowdsourcing as a single source of disaster response data is universally not accepted as best practice.

4.3.2 Civil Defence and Emergency Management Themes

- Actively developing crowdsourced application
  - Currently there are groups within CDEM who are creating crowdsourced applications and testing their capacity to work in a disaster. Most notable is the online reporting portal being set up by Emergency Management Southland.
- Capability of setting up crowdsourced data campaigns
  - Participants from CDEM agencies reference previous disasters in which different forms of crowdsourcing has happened.

4.3.3 New Zealand Red Cross Themes

- Development of crowdsourced data not a high priority.
  - In interviewing Mat Darling from NZRC it became clear that the Red Cross's role in disasters involves less management of information and more using their DWST resources to deal with issues passed on by CIMS. Additionally the view that crowdsourced data may exclude some venerable people and that door to door surveys with find those people, can explain why NZRC in general is not focusing as much on crowdsourcing.

4.3.4 Geospatial Intelligence New Zealand Themes

- Crowdsourcing represents a supplement to foundation datasets

- Through these interviews it became clear that existing sources of crowdsourcing, particularly OpenStreetMap, are highly valued for their potential to add to existing datasets. A special mention was mentioned by GNZ staff to how OpenStreetMap can provide up to date information particularly overseas in the South-Pacific. Notably this element of crowdsourcing was not viewed as being as important in New Zealand due to the pre-existing datasets from supplies like LINZ.

4.3.5 Ngāi Tahu Themes

- Individual perspective offers a highly valuable contribution to responding after a natural disaster. It was strongly noted that people should be able to give their own views and express what they feel is impacting them the most
    - Additionally a theme was that government organisations should not have full control over what information is given as there is a concern of bias.
- Local involvement leads to better recovery outcomes with people becoming empowered to help themselves.
- Existing social networks within Ngāi Tahu Iwi allowed for effective recovery strategy after the 2011 Christchurch earthquake.

4.3.6 NZRC and CDEM common themes

- Most venerable people risk being excluded in crowdsourcing
    - This view, held strongly by Red Cross, was also shared as a concern by Civil Defence participants. The recognised that crowdsourced data is limited by individuals access to cellular and internet coverage which can be severely limited during a disaster, particularly so during the response phase.

4.3.7 CDEM and GNZ common themes

- Crowdsourcing policy should be at a national level
    - Both participants from CDEM and GNZ note that organisational policy has a significant role in the adoption of crowdsourced data. To this end CDEM talked about how a national approach to introducing crowdsourced data is needed to ensure consistency and make crowdsourced applications (and the teams to analyse the data) affordable. GNZ adds to this idea by noting that the scale of

organisations involved in disaster response means that even small changes become very complex, and to add widespread crowdsourcing will take time.

- More collaboration needed – agencies and crowdsource volunteers
    - Both these agencies agree that if crowdsourcing is to progress into the future then it will either be internally directed and run or will involve outside volunteer groups. The former carries risks of bias in information gathered, while the later involves developing connections that do not currently exist. In regards to the later both agencies agree that steps to work not just amongst fellow agencies but also with community groups and crowdsourced initiatives is an important part of using this data in the future.
- Geotagged photos a trusted form of crowdsourcing
    - Highlighted in all the interviews across CDEM and GNZ participants is the strong associated value with crowdsourced images, particularly those with geotags. The level of trust in images far exceeds written or verbal reports (while verbal reports are favoured because of the effort in contacting a response agency).
- Crowdsourced data actively used
    - Both these agencies report using crowdsourced data in disaster response operations, either in the form of; longstanding datasets such as OpenStreetMap, crowdsourced campaigns by reputable groups such as TomNod, or more generally using social media to gain situational awareness.

Chapter 5 – Discussion and Recommendations

5.1. Discussion of findings

5.1.1. How is crowdsourcing viewed by response agencies?

As presented in the literature review, response agencies in international case studies could be generalised as having a low opinion of crowdsourcing. In general crowdsourcing is not trusted; perceived issues with accuracy and with who is producing the data contribute to this lack of trust. The case studies in which NGO or government organisations' opinions are noted are usually in reference to Ushahidi application, and in at least one instance, (2008 Kenyan elections) Ushahidi organisers were in conflict with the then-in-power government's interests. In other instances the issues were less consequential than in a conflict situation but in general there were trust issues around the quality of data. Johnson and Sieber (2013) noted how 'trust' in data is an important determining factor in organisations' using a data source, and Lee (2016) supports this with a Korea-specific observation. This is a widely accepted perspective and is also made note of in Goodchild (2007), Haklay (2010) and Meier (2012).

Counter to this 'lack of trust' is the positive opinion of New Zealand response agencies towards the idea of CGI. When asked, all participants agreed that there is application of crowdsourced information in disaster response. The most significant variation in the responses was on how crowdsourcing could be applied, as opposed to its level of usefulness, which I would characterise as being perceived as high. Of importance here is recognising that there is a difference between crowdsourced data and crowdsourcing collection. While all agree that crowdsourcing is an objective good, there is more diversity of opinion regarding who should be collecting this information.

In regards to collecting information, a clear difference between the opinions of New Zealand NGOs (Red Cross and Ngāi Tahu) and the response arms of the government. While there was a variety of opinions expressed across the Civil Defence and NZDF interviews, they came back to a model of government implemented crowdsourcing where the public would send them information. The NGO interviews on the other hand suggested that, from an ethical perspective, the information provided should be driven by citizens and their perceived needs. Initially, this appeared as a fairly salient difference, however, after consideration, it forms one of the most

important decisions any future crowdsourcing system will need to address; who decides what information is important?

The significance of a New Zealand perspective is that it would seem agencies have less apprehension around engaging with CGI in general. This I attribute to two important recurring comments: the first being that agencies typically view every source of data critically and do not take anything as automatically correct, allowing for CGI to fit into data assessment workflow easily; the second is that the value of highly up-to-date information can outweigh the perceived issues when implemented with caution and in conjunction with other information.

5.1.2. What specific information should be collected?

In responding to crises one of the most important factors for success is access to good information (Cutter, 2006; Goodchild and Glennon, 2010; McDougall, 2012). Information needed in this area includes base infrastructure data, topography and weather data, and hazard information. These data are generally at hand during a response operation (Cutter, 2006), however what is not as readily available is information on current conditions of infrastructure and people impacted (Goodchild and Glennon, 2010). This point in raised in many papers examining CGI which praise the temporal quality of CGI as a solution to this issue (e.g. Bruns, 2014; Elwood et al, 2017; Haklay 2010; Starbird, 2011).

A focus of the interviews was on what information was wanted by response agencies. To this, an interesting answer which several participants gave was, “anything [they] can get”. With the considerable time pressure and the scale of impact some natural events have on areas, a real pressure experienced is a lack of current information. Particularly, NZDF and Civil Defence participants noted that in New Zealand they are fortunate to have large amounts of base data and technical expertise to predict possible impacts of different disasters. What is lacking, however, is specifics of where people have been impacted. For instance, while models have been developed to predict flooding, the actual impact during an event is often different to a degree. To this end, response agencies are interested in any information that may help understand the situation better.

While more information is often better, as described by response agencies, there was consensus on more useful pieces of information for response operations and the type of information given. Specifically, Civil Defence wants information critical to people’s direct physical safety; food, water, and shelter access, property issues such as sewage leaks or significant damage, and infrastructure damage. While the NZDF, as a logistical arm of response efforts, wants to know

information such as road issues, suitable sites for helicopter or aeroplane access, and what resources are available (to determine the type of aid that they will supply). Furthermore, a strongly held view across these interviews was that crowdsourced data, when supplied with photographic evidence, was the best form of data available. This was attributed to the increased level of trust in photography, the ability to make internal assessments of the ground situation, and the ability to direct a member of the public (in a direct crowdsourced feed such a video call) to look at key details that experts can use to make remote judgements. This information relates directly to the purpose of these agencies, and certainly can be addressed by crowdsourced data, however it is not everything that is produced when engaging with the public. Crowdsourced data can go beyond just reports of damage, and access to food, water, and shelter, but can give both a sense of need as well as expressing hardship in less measurable terms.

One key identified by both of the NGO participants, was how when people in need are asked broad questions regarding their welfare, the information gathered is richer, and gives a much more holistic understanding of need. For many, during disasters, need is not measured in litres of water or cans of food but in concern for the future of their farm or anxiety about friends and family that have not been contacted. These represent another aspect of harm caused by disasters; emotional stress. In this regard, and while response agencies may not be able to directly alleviate all of this, crowdsourcing represents an avenue for a form of data on an impact previously untraceable; harm. There is an opportunity for disaster response agencies here in this form of information, as the ability to track and analyse patterns of harm as part of longer term plans to deal with the aftermath of a disaster. Additionally this is a direct form of aid, which community organisations like Ngāi Tahu or humanitarian missions like the Red Cross, can address.

Participants in this research have provided helpful insight into what information is needed for response. Based on what is currently being used, and what is desired on the part of agencies, it is clear that CGI has the capability to fill in some of the gaps left by traditional reconnaissance and situational awareness efforts. This is in agreement with the literature which generally praises CGI as offering a solution the difficult question of how to develop a dynamic situational awareness.

5.1.3. Effective use of social media or indirect/non-volunteered crowdsourcing

Social media-sourced CGI is a very popular source of information, it is easily accessible, already publicly available, and captures an audience that may otherwise not engage with crowdsourcing (Ahmed and Sargent, 2014; Bruns, 2014; Coleman et al., 2009; Rouse et al., 2009). Coleman et al. (2009) explained that people experience different motivations when contributing to CGI, and social media is likely one of the largest categories in data quantity as it is a passive form of contribution. This is supported by Heipke (2010) with the identified CGI contributor category of 'Passive mappers'. Passive mappers contribute through outputs not intended for use in crowdsourcing. This actually gives one potential advantage over direct crowdsourcing as the content is made without a creator's bias. Additionally with location-based technology the output in becoming increasing spatially accurate.

What is clear from the interviews with all agencies is that social media forms a large component of their information gathering processes. Additionally, social media is used as a primary method of communication to the public, particularly among the younger demographics. This means that social media as a form of crowdsourcing could be considered to be a disaster response agencies largest step in the direction of crowdsourced data. This step, however, is notably rooted in direct data manipulation through direct staff monitoring of social media, and extrapolating information and patterns through this. However, this is in conflict with the most recent literature on the subject of social media crowdsourcing. The literature on the subject focuses on the use of software tools to directly take social media feeds and translate them into usable intelligence. This research holds particular importance, as social media has been being used more in disasters; evident from both the numbers of discrete posts relating to disaster events, and social media sites implementing disaster specific functions such as Facebook's 'Check in' system. If the trend continues, then it can be reasoned that social media posts during disasters will become more and more difficult to manage manually. The issue is compounded by an assumption that the more disaster response agencies engage online with the public, the more return information will be received through social media.

Indirect crowdsourcing in New Zealand has been popular for disaster response, with large amounts of posts being made during a natural event. Local agencies have been able to employ teams to comb through these data to help develop situational awareness. What is less clear however is if New Zealanders will be more or less likely to engage with direct crowdsourcing on the same level they do with social media. Literature suggests it will be probably less as it

requires less effort to contribute to social media (as well as it being part of everyday life for many anyway) but this cannot be known for certain.

5.1.4. New Zealand Civil Defence test crowdsourcing system and how it has influenced recommendations

The last part of this thesis addresses a set of recommendations directed towards government response agencies, all of which centre around a proposed crowdsourcing system. This proposed crowdsourcing system draws inspiration from Ushahidi (Okolloh, 2009), as well as lessons learned about grassroots crowdsourcing efforts, but uses Emergency Management Southland's (in-development at time of writing) crowdsourcing application as a structure. Specific lessons learnt include: CGI platforms benefit from using multiple input sources (Heinzelman and Walters, 2010), helping to maximise data collection; the increase in bulk data can create issues (Munro, 2010), however crowdsourcing labour can be a potential solution (Neis and Zipf, 2012); citizens can be very effectively mobilised to respond to specific events evident through the Humanitarian OpenStreetMap Team program (Neis and Zipf, 2012; Palen et al., 2015) and the GEO-CAN engagement (Ghosh, 2011).

Emergency Management Southland's crowdsourced system is a web portal showing an interactive map of the Southland region. To contribute, users take the following steps:

1. Access the web page through the Emergency Management Southland website
2. The user creates a report based on a location (searchable)
    a. Report contains a location coordinate, a type of incident (from a dropdown menu), and a description of the issue.
3. The report is uploaded with contributors contact information to Civil Defence.
4. Civil Defence then uses data for response
5. Reports can be posted publicly if Civil Defence wishes, with only a user's own posts being viewable before this.

While this is only in development, it does provide a solid, and tested (in simulated scenarios), foundation to model a system on. Key points about this system include identifying the contributor; giving contributors a simple user interface; and providing categories of incidents. By identifying the contributor, it is believed that this ensures accuracy by making contributors accountable for any potentially misleading reports. The simple user interface allows people to find or search for locations of an incident, which encourages people who are not as technologically literate to use the system. Finally, by providing a dropdown menu, it both gives

ease of use to the contributors, and can focus responses into discrete categories for improved usability by responding agencies.

The platform by Emergency Management Southland makes some very positive steps towards effective crowdsourcing based on an academic understanding. The strength of this platform is that it focuses on specific events and a call for responses by the local authorities. This encourages participation as well as providing a good mechanism for input through a web portal. Improvements include expanding mechanisms for input from SMS, email, and direct calls, however there is not enough research at present to assess how effective these alternative mechanisms would be in a New Zealand environment. Additionally, literature highlights the power of crowdsourced labour for processing information which the system in its present design does not take advantage of.

5.1.5. Who does crowdsourcing serve, response agencies or the public?

Crowdsourcing is often viewed from the perspective of the end-consumers of the data; these naturally are often response agencies (Goodchild, 2007). For this reason CGI research can easily become over-focused on what crowdsourcing can do for agencies and not what it can do for the contributors. Some authors have addressed this (Chilton, 2009; Elwood, 2008; Goodchild, 2007; Lee, 2016) and note that CGI research needs to examine the social benefit of crowdsourcing. Research in this field concludes that CGI offers not only benefit to users but also to the people who engage with it. This happens in two respects: the first is CGI allows a mechanism of communication between people and has been particularly prevalent in crisis Ushahidi applications (Martin-Shields and Stones, 2014; Okolloh, 2009; Yates and Paquette, 2011); Secondly it also helps people create a sense of ownership over their information and contributions, particularly noticeable in OpenStreetMap which created a community of contributors (Chilton, 2009; Haklay, 2010). These benefits should not be overlooked and provide a justification for including citizens in the development of a crowdsourced platform.

The interviews conducted by this study can be broken into two primary groups; government, and non-government agencies. This division is most strongly exemplified in approaches to whom crowdsourcing should serve. It is clear from these interviews that CDEM and GNZ view crowdsourcing as a method to assist in better, more informed, decision making. For these agencies, crowdsourced data is about the collection of information. Contrasting this, NZRC and Ngāi Tahu, while not as involved in crowdsourced data discussions, view crowdsourcing

as a tool of the public to express what is important to them. This dichotomy touches on an important aspect of CGI research; should crowdsourcing be directed to create more efficient and relevant data, or should crowdsourcing be used as a way to see what is most important to contributors by viewing what is presented as a whole? Ngāi Tahu urged for a community driven approach to CGI, and warned of imposing an external criteria on data collected. Their concern was that a government driven crowdsourcing campaign may not collect information that reflects the true depth of an individual's impact from an event, including both physical and spiritual/community needs.

After considering the responses from each participant, the agency-directed crowdsourcing by Emergency Management Southland, and how crowdsourcing has been utilised overseas with the community-driven Ushahidi and OpenStreetMap platforms, the conclusion drawn is that a structured platform is needed to meet response agency needs, but without community engagement the system will be flawed. It is clear that unstructured data would prevent a lot of the benefits crowdsourcing offers, particularly in terms of timeliness, which is a key factor in response effectiveness. However, an individual's situation is much more complicated than a dropdown menu on an interface could address, particularly if that person is to be able to give response agencies a holistic understanding of their situation. It is the opinion of this thesis that any crowdsourced platform that is created needs to first address the question of: aside from facilitating aid, what benefits does a system of communication and reporting offer a member of the public, and how can that be used for mutual benefit?

5.2. Recommendations

5.2.1. National level lead crowdsourcing effort

What became clear in interviews, particularly with members of Civil Defence and the NZDF, was that decisions relating to crowdsourcing would ultimately be made at a national level. While local Civil Defence agencies have the autonomy to pursue information from wherever they can source it, it was noted by almost all participants that a proper (direct) crowdsourcing campaign would be prohibitively expensive. This led to comments such as one from a Civil Defence manager that 'any real crowdsourcing across Civil Defence would need to be nationally lead and funded'. This, however, has not stopped some regional authorities from pursuing crowdsourcing, as is the case of Emergency Management Southland, although it must be remembered that this example is also a test case, and with a limited budget.

Comments referring to budgetary limitations, and an expressed high cost of producing software and web portals, leads me to conclude that if New Zealand is to have a robust source of (direct) crowdsourced data, then funding, if not leadership and direction, needs to come directly from the New Zealand Government. An important element found in the interviews was how, depending on the scale of the event, a different governing body would manage the response. For example, a local fire may fall the local city council and their Civil Defence team, but if that same fire was to cross over two districts then it may expand out to a regional Civil Defence response. From this, I believe that crowdsourced data collection needs to be standardised in some form, such as through the implementation of a crowdsourced platform that is on a national scale. This would allow for all response efforts from local to regional or national, and would all have the same type and format of information being collected. This would empower smaller response efforts to still use crowdsourced data despite its high start-up cost.

5.2.2. Community engagement and support for volunteer crowdsourcing initiatives

An area which is notably missing from the current New Zealand crowdsourcing space is a direct connection between the wider crowdsourcing community and response agencies. I believe that part of this is that crowdsourcing groups like what was seen in the Canterbury 2011 earthquake were formed in a reactive manner to a need. From overseas studies (Ahmed & Sargent, 2014; Bruns & Burgess, 2014; Martin-Shields & Stones, 2014; Munro, 2010; Soden & Palen, 2014), it is clear that having an established base of crowdsources can yield some incredible data that rivals government and private survey (see OpenStreetMap). These groups, however, were developed by initiatives, usually starting with simply an open platform being presented to people. The trend is that once a platform for crowdsourcing is created, the crowdsources will very likely follow on and create a self-sustaining community. This paper's recommendations largely focus around a MCDEM driven crowdsourced platform, however a strong recommendation is that work should be done to see how crowdsourcing can be used outside of disasters, as developing a network of dedicated volunteers will have a high likelihood of benefiting any crowdsourced effort during a disaster.

5.2.3. Efforts to increase literacy about the use of crowdsourced data

At present, most people, at least those with an internet connection, are already crowdsourcing contributors. However, most of these active contributors to the wider body of public data have likely never engaged with the idea of crowdsourcing, despite participating in it every time they create a Facebook post. This problem comes back to the idea of citizen GIScience, and

empowering people to contribute, with meaning, to a collective understanding of their world (Goodchild, 2007). People, at least from the numbers of people engaging in social media during a disaster, have an innate desire to share and to help. To this end, efforts are needed to eliminate the disconnect between people's ability to contribute, and their perceived value in their contributions, by creating a public understanding that an individual's experiences are important to people trying to respond to a disaster, whether that be from a person experiencing hardship or a person who has observed hardship. People need to be empowered to speak up and share information that normally is kept to themselves. In order to mitigate issues around lack of access to CGI caused by personal circumstance, this thesis recommends a CGI education campaign to go alongside a CGI application being deployed. While literature on CGI education is sparse, a logical step in this direction would be an associated awareness campaign around how any implemented crowdsourced platform worked, and how to use it effectively. For example, what information was desired and when should someone post or call emergency services instead. Further this is a valuable area of Geospatial Science and given its increasing prevalence in this field, should be a focus of geospatial education.

5.2.4. Further investigation into lessons from community support networks, such as Ngāi Tahu, and their impact on the speed of information.

From the interviews with Ngāi Tahu, it became clear that their information about iwi members was detailed and represented a positive outcome of communities communicating with each other during a disaster. Through community lists and interpersonal networks, the Joint Action Groups (JAGs) worked quickly to assess impacts on community members. A parallel can be drawn here with the initial community-driven roots of crowdsourcing, with Ushahidi and OSM as examples. In that regard it is the opinion of this thesis that JAGs, and their subsequent use in disaster response, provide further evidence that a community-driven CGI effort (perhaps supported by official agencies) also has merit in a New Zealand context. Further research is needed focusing on public opinion towards crowdsourcing to give a more definitive conclusion as to whether or not a citizen driven CGI would be effective.

5.2.5. A national level, regionally implemented, public disaster crowdsourcing platform.

As a product of this research I have designed a crowdsourced platform for implementation in New Zealand. Below is the structural outline for CGI platform potentially implemented by CDEM or another national-level agency. From here on it will be referred to as the Citizen Response Network (CRN). CRN is broken down into three sections, each described under the

headings; Purpose and Reach; Structure and Function; Funding and Authority; Issues Needing Addressing.

Purpose and Reach: CRN serves as a platform for all non-life-threatening emergencies during a natural event. It would function as an online platform that can receive communication from SMS, a call service, emails, and most importantly, an online hazard reporting website. The purpose of this would be to centralise information from the public during an event so as to provide a more efficient form of intelligence gathering. Additionally, the proposed system below explicitly seeks to mobilise the willingness and desire of people to help during times of emergency in such a way that some of the concerns raised through this thesis can be mitigated. This system is not designed to supersede CDEM EOCs, but to instead work within an EOC environment, or be run remotely in a large enough event (when outside volunteer staff would be used).

CRN has been thought of in the context of a national level application and would have a reach as such. However, and this is addressed in the final sub-heading (issues), there are still significant populations in New Zealand that during an emergency could be excluded from a system such as this. This means that it can be considered to have a wide reach, but with some significant blind spots that follow any system based in communications technology.

Structure and Function:

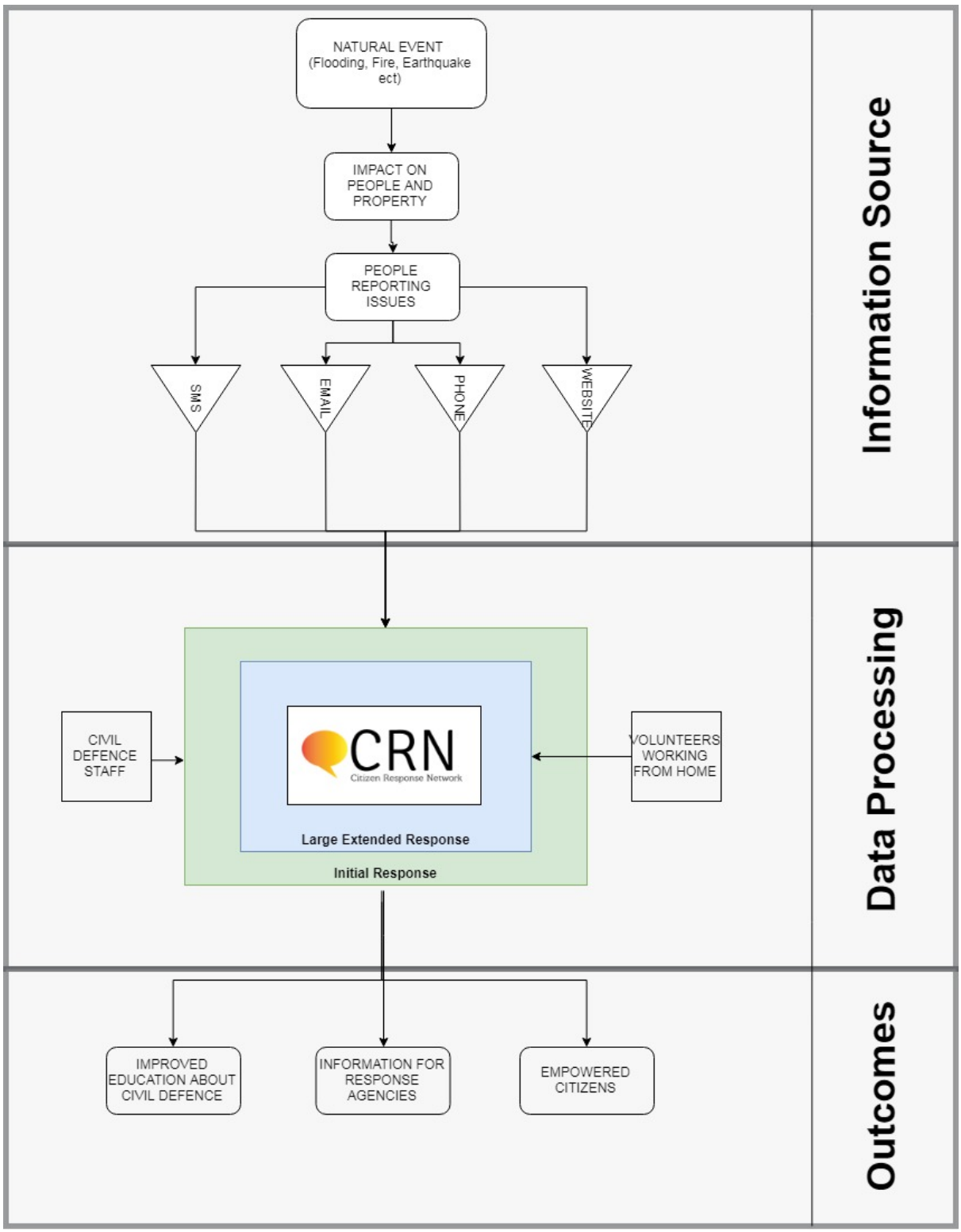

Figure 5. Proposed Citizen Response Network structure. See text for details.

The CRN is based on the Emergency Management Southland model altered to reflect the studies findings. Its sections are divided into; public impact and response (red); information processing (blue); and outputs of CRN (green). When an event occurs, the CRN gives an outlet for people to report issues caused by the event. This information is fed into the CRN through SMS, email, a direct phone service, and – most importantly – the online website. Information from SMS, email and phone will be manually entered into the web portal by CDEM staff. This information joins the publicly contributed data from the website (with staff entered data having already been assessed against the criteria of urgency and suggested reliability). From here, it is accessed by the CDEM intelligence team who will view reports through a GIS application for Direct Response Efforts (DRE) and pattern analysis. Analysis of the data is something that would require training and more highly skilled workers, and as such, CRN offers a form of citizen mobilisation to counteract the pressure on CDEM staff during periods of high information intake. CRN proposes to engage with volunteers before a natural hazard event occurs, and have a pre-existing body of workers who can take the SMS, email and phone inputs and convert them to GIS entries for CDEM to make decisions from. From here, the output of CRN is a direct feed of single-source crowdsourced data, and social flow-on effects of citizen empowerment (through volunteers), and improved education about disasters (from implementing an interactive CDEM system).

Funding and authority: as established above, local and regional Civil Defence organisations do not have the financial capability to pursue a project such as this at the scale proposed. This lends itself to the conclusion that the only other reasonable source of funding falls to the central New Zealand Government, specifically MCDEM. While this may initially seem to be an issue for the government with a very high cost for what is another source of data, I believe it is important to also understand the benefit of a centralised authority. One of the elements brought to my attention during these interviews was that different agencies deal with disaster information differently. This can cause inefficiencies in collection, and a central authority would allow for greater control over data acquisition. This element, while a boon to CDEM operations does raise what is probably the greatest flaw in the CRN, a government focused collection.

Issues needing addressing: The model proposed here has been formed with an efficient model of centralisation and government authority of the system. This, however, is in contradiction with the philosophical point of crowdsourcing; to be a free flow of information from the public. To this end, I believe it would be very unwise to implement any form of national

crowdsourcing, without seriously addressing the two following questions; who directs what sort of information should be collected; and, should information be isolated to response agencies or republished to the public to empower citizen response. The following two paragraphs briefly address these questions to explain how they apply to the CRN model but do not offer an answer; only a strong recommendation of how to approach solving these.

This CRN model does not specify the questions or specific information requests, although it can be inferred by the reader that there is a more focused collection effort to facilitate efficient data analysis. To this end, what questions are asked of the public becomes critically important, not only for how useful the information collected is, but also for how well the system addresses community needs. Raised both by the Red Cross and Ngāi Tahu was the concern around bias of information collected by government agencies such as Civil Defence. In these interviews, they advocated for a grassroots collection methodology in which affected communities determine what information they want to share as it relates to their perceived needs. The difference between these potential viewpoints is something that should be investigated further through workshops to examine what peoples perceived needs are post-disaster.

CRN in its proposed form is, for the most part, a one-way flow of information. Members of the public volunteer information to CRN, and while some of the (citizen) volunteer's access this information, the results are published internally within the EOC structure. This system is a logical place to start, as it ensures that information is provided to response agencies for decision making. CRN in this form of output however, excludes the general public from making use of the information collected. The question of which approach, closed or open access, is best remains controversial. Raised in the interviews with CDEM and GNZ, it was clear that the view was that responders need to be cautious with information received, as it can be inaccurate or incomplete. This cautious approach allows for further investigation and care consideration before a direct response is attempted. Conversely the general public isn't as restricted and could directly respond to reports, potentially helping or harming the situation depending on many variables. From the literature however, we know that when crowdsourcing is done in a grassroots manner (international Ushahidi case studies being the prime example) there have been very positive results. As there are conflicting viewpoints, further workshopping needs to be done to come to a decision of how much the public should be able to access with regard to consolidated information. This paper holds the opinion that to maintain the integrity of a crowdsourced system, citizen direct response needs to also be facilitated. It is suggested then

that a secondary (public) output is created which shows validated information of reports that people can help with directly, for instance people needing transport to welfare centres. This idea does carry significant legal challenges and will need to be considered carefully before any public implementation is done.

Chapter 6 - Summary & Conclusions

6.1. Summary

Crowdsourced information has become an increasingly relevant part of geospatial data collection. This is true across various fields within GIS, but particularly so in disaster response work. CGI or VGI presents a few distinct advantages to the more traditional sources which have the potential to advance decision making in an event. These advantages include; a high degree to temporal relevance, or information being near to 'real-time'; information coming from direct observations of an event site; the data collection process acting as a method of communication for people in a difficult and venerable situation; and crowdsourcing as a concept having the potential to give insight to response agencies about the issues which are most prevalent to victims of disasters.

Research in this field has been largely focused overseas, and often concerns places with less developed infrastructure and response networks than New Zealand. Further, the research that has involved New Zealand, while providing excellent insight into case studies of events and the crowdsourced products of those events, has had a relatively narrow focus. To this end, this thesis was designed to answer a fairly broad question with a specific audience; how can crowdsourced data be used by New Zealand responders to improve response to a natural event impacting people and/or infrastructure? To understand this, lessons from literature were needed.

In examining the literature on the subject (Ahmed and Sargent, 2014; Bruns and Burgess, 2014; Martin-Shields and Stones, 2014; McDougall, 2012; Palen et al, 2015; Yates and Paquette, 2011; Zook et al, 2010), it was found that crowdsourced data had been used very effectively overseas to help deal with events. This often came back to specific applications of crowdsourcing, including; OpenStreetMap, a road/infrastructure map similar in function to a publicly generated version of GoogleMaps; and Ushahidi, a crowdsourcing platform driven by those directly impacted by an event. Case studies surrounding these applications yielded several lessons including:

- People are naturally driven to communicate, and this can be used to gain a level of situational awareness not possible elsewhere
- Crowdsourcing serves as both a tool for response agencies, but also a support network for private citizens

- Crowdsourcing is not a perfect source of information, but as they become used more often, crowdsourced systems have found ways to improve information, such as OpenStreetMap's system of prioritising known contributors.
- Social media has a huge role in crowdsourcing and this information is becoming increasingly socialised, with much of it being geotagged.

These lessons were taken, and used to establish core questions to be used in a series of interviews with key informants. Interviews were used as the primary source of information to inform this study, as, by talking with experts working in New Zealand response, it would be possible to gauge the following:

- How the New Zealand specific conditions impact on our response/data used, compared to the overseas use of such data.
- Develop a baseline for how crowdsourced data is viewed, as well as get expert opinions on how it could be used in New Zealand
- Discover any existing uses of crowdsourced data, and use this to develop a series of recommendations of how best to use CGI in New Zealand.

Thematic analysis of 9 interviews revealed patterns and areas of both agreement, and contention, between participants. This analysis generated the findings of this study, and the conclusions of how crowdsourced data can be used to aid disaster response.

6.2. Conclusions

Several themes were established relating to how New Zealand response agencies use information for decision making, and how crowdsourced data fits into their processes and wider discussions. In terms of general themes, it was discovered that:

- Crowdsourcing as an idea was advocated by all participants. Its value in providing timely and 'ground-level' information was considered as being of importance by response agencies.
- At present, crowdsourcing, with exception of Emergency Management Southland's test, is confined to social media, and limited direct information provided to local/regional councils.

- Agencies recognise that work done in preparation (Reduction to Readiness) to identify where response is needed is only an estimation. Once an event happens, the actual places where people are in need is largely unknown until response teams provide that information. Crowdsourcing is acknowledged as a way to speed up this process.
- Crowdsourcing is not a complete solution to the information problem, and is best used in conjunction with other sources.

Agency specific themes include:

- Civil Defence Emergency Management is in the process of developing a crowdsourced platform (at a single regional level at the time of writing). This comes from lessons learnt in other events where crisis maps, which are a form of crowdsourcing, has been used to a positive impact.
- The New Zealand Defence Force via Geospatial Intelligence New Zealand views crowdsourced data as an enhancer of existing foundational datasets (an opinion shared with CDEM), and sees potential in crowdsourcing supplementing these datasets, particularly as they can change rapidly in response to an event which is impacting infrastructure.
- The New Zealand Red Cross shared concerns that some people may be at risk of being excluded from crowdsourcing, either through event impacted communication issues, or being in an area that has a low level of ownership of technology/education around crowdsourcing.
- Ngāi Tahu urged for a community driven approach to crowdsourcing, and warned of imposing an external criteria on data collected. Their concern was that a government driven crowdsourcing campaign may not collect information that reflects the true depth of an individual's impact from an event, including both physical and spiritual/community needs.

The importance of developing a crowdsourcing platform in New Zealand evolved from the interviews. Aside from their agreement that this is a positive step, both agencies gave similar input regarding how it should be implemented:

- Any crowdsourcing platform in New Zealand that responds to an event needs to be delivered at a national level. This was supported by evidence in the case of Emergency Management Southland's crowdsourcing test. This test found that the cost of implementing a CGI platform is high. Furthermore to ensure quality/issues are met

effectively it needs to be standardised or risk having some systems being less effective than others.

- An area where these agencies need to progress, is engagement with external crowdsourcing groups. At this stage, there is a lack of communication with crowdsourcing groups, partially because these groups often self-establish in direct response to an event.

The themes presented here were considered, and related to insights gained from literature. From this, several recommendations were given; crowdsourcing should be at a national level and use the model presented (CRN) as a base; a form of community engagement and fostering of crowdsourced initiatives is needed; and, as part of community engagement, an awareness campaign of how people can contribute is needed for any crowdsourcing platform:

- Crowdsourcing is most logically implemented at a national level, and this paper proposes the Citizen Response Network to meet this. The CRN uses the framework of Emergency Management Southland's test but is not a complete model. It is essential that further development is done to address whether the public should be able to access this information, and how can the system be implemented to gain a holistic understanding of people's needs, as well as not excluding people with limited access to technology.
- Community engagement is highly recommended to address these major issues with the CRN model. By working with the community, as well as any groups – particularly those involved with the 2011 Christchurch Earthquake – who deal with crowdsourcing, CRN can be developed further to mitigate some of these issues. The hope is that talking with community groups can inform response agencies as to what those impacted would want to communicate and why.
- At present, CRN makes no attempt to address how to capture responses from all people impacted by an event. However, it is the recommendation of this thesis that this needs to be worked through before it is used in an event. A failure to do so could potentially result in people being missed and ignored amongst the information produced.

Crowdsourcing offers an excellent source of information with the potential to dramatically improve decision making in a disaster. This information needs to be harnessed as people already want to contribute to it. Disaster response work in New Zealand would continue to

benefit from implementing crowdsourced data more than they have already. It is advised, however, that as with any new source of information, its integration needs to be approached with caution in both how it can be used, as well as how it will impact the wider public in their new role as both victims of a disaster and as contributors to the response effort.

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Appendices

Appendix A: Questionnaire used during interviews

1. In the work you conduct on behalf of your organisation, has any of this been related to disaster response operations? If so, how would you characterise the work you do?
2. In broad terms, please describe the functions your organisation has in relation to planning/intelligence, both geospatial and otherwise?
3. Across planning/intelligence activities, what kinds of geographic information systems are used, and what products are made for the response effort?
4. What sources of data are used in these products, excluding crowdsourced data?
    a. Are these sources internal or external in nature?
    b. How would you characterise the data in terms of trustworthiness, accessibility, and level of relevance?
5. In the current state of disaster response, where are the major gaps in available information? What information would you want to access in an ideal situation?
6. Please take a moment to describe to me what your understanding of crowdsourced data is, and how it has been relevant to disaster response operations.
7. Has crowdsourced data been part of any operations you have conducted? And/or are there future plans to incorporate crowdsourced data into planning/intelligence operations?

The following questions relate to how crowdsourced data has been used internationally, and the findings of literature on the subject. Some will be preceded by a prefacing statement to provide insight or evidence related to the questions immediately following. Please answer the questions from your perspective as a professional in this field, and where possible from the perspective of your respective organisation.

8. Is your organisation aware of Ushahidi as a platform given its prevalence in disasters?
9. Will the source of the crowdsourced data influence response agencies' decisions (e.g. being done with support of volunteering professionals like Ushahidi's crisis group (volunteers often lead by professionals) or directly from the public (such as from Twitter and Facebook)?

Statement: In researching this topic, it was found that in several instances crowdsourced data collection was driven by individuals or community needs, and not by information requirements of response agencies that often used the data after collection had taken place.

10. If you could determine specific information collection efforts from the public, what would the focus be?
11. How would you characterise your organisation's relationship with the public through social media? Are there any systems in place to make use of social media and crowdsourcing platforms to communicate or collect information?

Statement: During the 2010 Chilean earthquake, a well-documented case of crowdsourcing being misused was a life-threatening situation being posted on the crisis map and over Twitter, prompting a response of 3 fire trucks and 30 police. This turned out to be a hoax report.

12. Do you have much concern over this kind of behaviour? With your current systems, what systems/processes are in place to deal with direct reports of people in trouble, if any?

Statement: Much research on crowdsourced data concerns the evolving forms of public use of social media technology to broadcast information and updates. The research also addresses methods or technologies that allow for filtering and verification of critical data.

13. As an organisation, do you have a focus on identifying new forms of data collection or data sources, or is the focus towards using existing forms of data more effectively, whether crowdsourced or otherwise?
14. How would the presence of a robust system for sorting through large amounts of social media posts, and displaying only relevant reports, impact on your current view of social media's application in planning and operations?

Statement: Some researchers have noted a lack of cooperation between volunteer map-making groups and professional organisations. This is often related to the idea that information from the public cannot be trusted, and that volunteers, while well-meaning, are not professionals with formal training in data quality and information production.

15. How would you describe interactions between your organisation and the wider volunteering community?

16. Have there been issues regarding access to information, or the publishing of information through systems such as the EQNZ (Earthquake New Zealand) crisis map for the 2011 Christchurch earthquakes?
17. Does the nature of the information collected, from whom and regarding what, change any of your above views? For example, would reports on non-life threatening issues, such as power outages or street flooding, be viewed differently to reports of trapped people or people in direct danger?

From our conversation here is there anything you would like to add to help inform my knowledge about crowdsourcing from the perspective of your organisation?

Appendix B: Detailed interview synopses

Please note – due to University of Canterbury Human Ethics Committee requirements, interviewee name, gender and role have been anonymised and replaced with "XXXX".

Interview 1: XXXX, Geospatial Intelligence New Zealand (GNZ), 21st July 2017

Method of interview: Zoom teleconference

- XXXX of Geospatial Intelligence New Zealand, an agency of the New Zealand Defence Force (NZDF). XXXX is the XXXX of this agency and through this work has extensive experience with GIS systems, partially as how they relate to decision making and policy matters.
- GNZ, as the spatial intelligence arm of the Defence Force, is tasked with providing maps and spatial information for the New Zealand Government during disaster operations. This information is used both from a ground level task management level in the form of map and intelligence products, and up to a policy level with disaster management decision makers in Civil Defence Emergency Management (CDEM) and the executive branch (New Zealand Government) strategy. XXXX characterises the work GNZ does as trying to provide an understanding of the situation to government decision makers, as well as providing as much information as possible for response agencies to be able to plan response tasks effectively. From a technical perspective, GNZ has the access to, and the capability to use most current GIS systems including online platforms for unclassified environments. These data are worked with Open Geospatial Consortium (OGC) formats to ensure other agencies can work with the data.
- XXXX characterises the sources of data used by GNZ as being 'well sourced from a foundation geospatial point of view'. Making reference to the use of Land Information New Zealand (LINZ) data sets, and the Defence Force's involvement in the Emergency Services Contract (a consortium of datasets and providers that is funded by the government). Additionally, being an NZDF agency, XXXX also notes that New Zealand defence assets can also collect data such as imagery and LiDAR, alongside private or public production of the same. Further, XXXX says that they will 'also take information from social media and media reporting to help provide that context to decision makers'.

- When asked about the applicability of these data, XXXX noted that ‘as professionals [they] can look at the data [they] have access to […] and see how that information was derived and created […] to weigh the decisions made against it’. To this, XXXX discussed how data taken from LINZ or the Emergency Services Contract could be taken at a better ‘face value’ than information from less well regulated and checked sources, such as social media. However, this section of our discussion also pointed out that no data are taken as being perfect, and that all information passed on has its limitations understood; for instance while LINZ data is highly accurate, it is only as current as when it was last surveyed. In this, XXXX noted that crowdsourced data from a temporal view can be very current, but you may need to note it as having potential inaccuracies. In general, and importantly, XXXX stressed that any data to be used needs to be examined and assessed for its usability. No data are automatically assumed as ‘good’, and this needs to be communicated to the decision makers or its nature.
- XXXX was asked if the data available now were sufficient. To this, XXXX noted that you will always want the best possible information, particularly with mission critical elements, but currently he agrees that there is a good spread of information available to this agency. XXXX said that better information can improve the outcomes, but only in the complete absence of information does a mission become compromised.

- XXXX defines crowdsourced data as ‘an environment where the general public can contribute to a geospatial picture’. Regarding how crowdsourced data has been used by GNZ, XXXX references OpenStreetMap (OSM) and how it can provide ‘a picture that is different to the picture they can provide’, and it ‘value adds’ to the understanding GNZ can provide. OSM has been used for ‘some time’ by GNZ, particularly in overseas operations. XXXX noted that, in planning, it can be useful to see differing perspectives that try to gain a more complete understanding of the operational area, and the crowdsourced platform OSM has been very useful for this from a geospatial point of view. In regards to more general intelligence collection, XXXX talks to the role of social media in informing understanding. Specifically, XXXX refers to cases where information from social media or news media discusses elements of a disaster that GNZ in interested in, such as damage to local infrastructure. These data create both a general understanding, and a more specific understanding of issues. As put by XXXX, ‘if there are comms, you can guarantee that the media and people will be out there with their

phones taking pictures.' This is information that XXXX views as an integral part of response operations. This information, particularly when attached to photographs, acts as a form of reconnaissance, and provides some relief in terms of taskings that have already been undertaken incidentally.

- When discussing crowdsourced data and potential limitations or flaws, XXXX noted that crowdsourced data are a different type of data from traditional sources of information. This is something that 'needs to be understood' in its implementation. The understanding gained from this, is that as crowdsourced data do not follow a production method users are familiar with – such as a single author with quality control measures in place – there will be a learning curve to understanding how crowdsourced data can be used, where can it be used well, and where will it experience issues.
- XXXX noted that the potential issues around crowdsourced data – errors and inaccuracies – are largely not considered to be a problem for GNZ. XXXX said that as GNZ looks at larger scale information such as access to infrastructure (water, sewage, and power), individual reports are not as much of a concern. This XXXX attributes to two factors; the first being the level of verification that any data to be used goes through which would highlight any issues; and the second is that at the scale being examined (area patterns), individual incorrect features or reports will not impact the overall picture, which is their goal.
- XXXX spoke positively towards the future of crowdsourcing within not just GNZ, but more generally for how crowdsourcing will play a greater role in GIS in general. XXXX spoke of how military efforts to map the world have been conducted for as long as there were militaries to map with. However, with the advent of crowdsourcing, the potential for many people to be acting in place of what would be traditional activities, such as surveying an area for damage, can now potentially be undertaken by people already doing so. People do this currently by documenting the world around them, through either social media posts or more deliberate efforts. The potential for providing current, up to date information ('although a different type of information that needs to be understood') is huge. From our conversation, it would seem that it is a matter of people utilising this new resource and viewing it as a potential source for providing understanding of a disaster situation.
- Additional to the utilisation of social medial for understanding a situation, XXXX also envisions the power of crowdsourced processing. Specifically, XXXX spoke of the idea

of immersive capture of a disaster space, rather than feature specific capture. The idea of this method of data collection is that through a cloud based crowdsourcing campaign, you can work through massive amounts of data to find these features of interest. This approach is in reverse and has the distance advantage of being able to identify potentially more features of interest. XXXX did reference a notable turning point in the acceptance of crowdsourced data as a potential method of understanding our world. This was the 'emotional acceptance of OpenStreetMap; emotional acceptance as a way of saying this is something we cannot ignore and must embrace'. This acceptance is key to allowing people access to contribute in such a manner.

- When discussing interactions outside of GNZ, XXXX explained that being a Government agency, and one that operates within a secure classified environment, there are some limitations to access or sharing of systems. Regarding disaster response operations however, and particularly in a domestic context, this is largely conducted in an unclassified environment as there is such a high degree of cooperation between GNZ and outside agencies. This cooperation has not extended as much to volunteer groups that tend to form during disasters to collect and process information, although these have not been seen widely by GNZ in their work, as they mainly deal with CDEM and Government. Regarding this, XXXX noted that technology and people, as evidenced by OpenStreetMap, will become more prevalent, regardless of GNZ's position. As such, he views increased engagement with this element of data collection as being an important step in the future of disaster response. Specifics on how future implementation of crowdsourced data and groups of volunteers would work were not given, as this is still a new topic within the disaster response sphere.

***Themes*:**

- Considerable cooperation between agencies.
- Existing use of reputable source of crowdsourced data, OpenStreetMap.
- Favourable view towards crowdsourcing in future applications.
- Issues with perceived crowdsourced issues not relevant for NZDF due to wider focus.
- Existing datasets sufficient for baseline* data in New Zealand.
- Advocated for the value of immersive (widespread) capture of crowdsourced data.
- NZDF focuses on situational awareness over specific incident management.

**Baseline refers to foundation datasets such as infrastructure and demographics.*

Interview 2: XXXX, Canterbury Civil Defence Emergency Management Group (CCDEM), 22nd August 2017

Method of interview: Zoom teleconference

- XXXX is the XXXX of Canterbury Civil Defence Management (CCDEM), the Canterbury region's branch of CDEM. The work XXXX does is planning for CCDEM during the readiness phase of disaster response work. This makes XXXX a suitable informant, as XXXX is very familiar with disaster response work, particularly as it applies to working with and communicating critical information between different agencies in Canterbury. Additionally, XXXX is currently working on developing tools to be used in an EOC; a significant component of this is in tracking events and reports during a disaster. During a disaster, XXXX operates within the intelligence and planning function, making XXXX qualified to respond to these questions. Further, during the course of XXXX tenure, XXXX has been involved in numerous activations, including the Port Hill Fires (a large forest fire in the Christchurch City area known as the Port Hills, 2017), and the Kaikōura Earthquake (a 7.8 M_w earthquake in November 2016).
- CCDEM is responsible for both preparation and direct action related to disasters in the Canterbury region. They are the formal government arm of disaster response in Canterbury, and have associated powers including the ability to declare an emergency for the region. Functionally speaking, they set up and operate EOCs during disasters where all agencies meet to liaise and plan for tasks and actions to be conducted. This is facilitated by duty officers, of which XXXX is one, who are on call to respond to any disasters as they occur, or with early warning from sensors where this is possible.
- CDEM deals with emergency management using the 4 Rs (Reduction, Readiness, Response and Recovery). As such, the requirements for data change between the different stages, however when it comes to spatial data, this is primarily during the response and recovery phases. Reduction and Readiness are primarily concerned with identifying hazards and potential scenarios for harm during a natural event. As such, the ownership of these data lies with local authorities to plan for their own areas. During the response phase, CCDEM is primarily focused on responding to direct issues arising from a natural event. During this phase, the ownership of data, and therefore decisions made from the data, falls to the authorities with a civil defence mandate; primarily CDEM, but also emergency services and Government Ministries and Departments.

Response is characterised by the use of Coordinated Incident Management Systems (CIMS). A system that uses spatial and other data sources to identify areas of need for ground teams to deal with. Response activities are also time sensitive, and as such, data which are current has a high value. The Recovery phase is about returning communities to what XXXX terms as a "new normal". This is based on strategic planning to redesign communities to be more resilient in the future, and to help people get back to their everyday lives. As such this data falls back to local authorities with support from the government.

- XXXX went on to explain about the relationship between CDEM and local authorities, as it relates to disasters. Specifically XXXX explained that local authorities are responsible for incidents in their area, as well as planning; the uses of data that this study would be concerned with. If an event has a significant enough impact, then CDEM can be activated at a regional level, then a national level, at which point this information flow includes them. As such, the statements above can change depending on the scale and the specific disaster, but in general; Readiness is about identifying areas of vulnerability; Response is about incident identification; and Recovery is about planning for a long term return to a 'new normal'.
- From a technological perspective, XXXX discussed the utilisation of ESRI products to work towards a future goal of having maps, and information resources to support a response plan. This would integrate data from various sources so that in the event of a disaster – or as a tool for planning – a better understanding of the situation on the ground can be easily accessed. For example, XXXX has been working on the Canterbury Tsunami response plan. Within this response plan, XXXX has been looking at developing a GIS web application to store and reflect the information contained in said plan. This is so that in the event of a disaster, they will have easy access to all of the key pieces of information. These data come from public sources such as Land Information New Zealand (LINZ). Looking further into the future is the integration of other sources such as lifeline utility information (power systems).
- When asked about current data being used and its limitations, XXXX said that it is a difficult question to answer as it will vary hugely between different disasters. However, there is a lot of base line information that will always be used regardless of events; roads, powerlines, waterways, property boundaries, etc. These data have been collected by CCDEM over a long period of time, however there are issues around the

consolidation of data between individual Territorial Authorities (TA). Additionally, some data have been characterised as incomplete, or do not include the specifics that are useful for response work; property parcel data can be useful to identify areas where people are, however may not include data such as who is living there, or how to contact them, as this is determined by the individual TA, and the information that they choose to collect. One form of mitigation noted by XXXX is a system implemented by the Christchurch TA (the Christchurch City Council, CCC). This was an online registration form, from people impacted by the earthquake; a dataset that then was used by the CCDEM.

- Crowdsourcing is defined by XXXX as publicly available information that has been collected, and aggregated into what is generally a public website. These data can be added by anyone, such as individuals trying to help, or organisations [non-profits] trying to help, or as part of the official response. XXXX examples a hypothetical system where people could upload geotagged photos. For CCDEM, crowdsourced data have not been integrated into responses to date. However, XXXX expressed that this does not mean CCDEM does not want to have a 'public facing tool to submit text, video or photo evidence of something'. Ideally, XXXX said this would be beneficial and a source of intelligence from volunteered information such as this. This tool has not been created to date, nor has it gone through the process of figuring out how it would fit into a current EOC structure.
- When XXXX was asked when believed that this may be integrated into CCDEM, XXXX noted that the technology for crowdsourcing has been around for at least a decade. XXXX went on to say that from a technical standpoint, crowdsourcing in New Zealand by CCDEM can be done currently, and already has been to a lesser extent. Specifically, XXXX references a public photo viewer set up by Eagle Technology for the Edgecumbe Flooding (April 2017). However, while this has been set up, the associated technical arrangements, such as training, and intelligence personnel to process the information has not be arranged. From a single event perspective, CCDEM is currently able to, within a few hours of an event, set up some form of basic crowdsourcing. From a more established perspective with crowdsourcing technologies being integrated into future response operations, this is still potentially some time away (interpreted as a few years at least from descriptions of system integration and how long

that takes). It is something that is desired, but the path to get to there has yet to be decided.

- In terms of how to integrate crowdsourced data into New Zealand disaster response, XXXX discussed the EQNZ website; how it developed, and how that can be compared to findings from crowdsourced data workshops (as part of US Disaster Relief Camps) held out of Camp Robertson in the United States. Specifically, XXXX explained the EQNZ website that was established in response to the Christchurch earthquake. This goes against the lessons learned from crowdsourced data workshops, which suggest that pre-established connections between volunteer individuals and groups, and the agencies who use these data during a disaster, would improve the outcomes of this kind of activity.
- A lesson learned though the camps mentioned above include where issues can arise from lack of communication between the people setting up crowdsourced data collections, and response agencies. Specifically, XXXX mentions that unless the generators of crowdsourced data understand the systems in which the data are going to be used, then they may be trying to fulfil a need that is already being satisfied elsewhere. To this end, XXXX saw less of an issue with the data created, and more of an issue as how that data relates to other information that is also being collected. This, XXXX says, can be mitigated by forming relationships with the people and groups interested in producing this kind of information.
- Regarding the specific information that is incorrect, CCDEM has had experience with this through social media already. XXXX notes that, usually, it is not incorrect information so much as it is misunderstood information. Another way in which XXXX explains this is that, often, the issues are around public posts of an "issue" that has in fact already been dealt with, or is in fact not actually an issue at all. This results in wasted resources through reassuring the public and correcting the information. XXXX notes that if there was a system for this information that was already used, then these issues could be handled before they have the potential to misinform the public.
- The next steps for CCDEM are to examine how a crowdsourced data application or system can be integrated into CCDEM processes. This involves examining how existing technologies can be most effectively used (in terms of cost) as well as understanding how they would fit within the relationships between stakeholders. This, naturally, would also involve engaging with groups and individuals that are interested

in volunteer crowdsourcing. As stated before, XXXX believes that close engagement with both the public, and potential crowdsources, is the best way, moving forwards, to having this in the future.

Themes:

- Information requirements vary between the different stages of the response cycle.
- Crowdsourced data through geotagged photos highlighted as a useful source.
- A crowdsourced platform is desired but not currently widespread within CDEM.
- Issues in consolidating data from TAs to a CDEM regional EOC.
- Crowdsourcing in unstructured ways can lead to inefficiencies and doubling up of work.
- CDEM is capable at this point in setting up a basic crowdsourcing platform in response to a disaster.
- Social media is the primary method of crowdsourcing.

Interview 3: XXXX, Canterbury Civil Defence Emergency Management Group (CCDEM), 22nd August 2017

Method of interview: Zoom teleconference

- XXXX being CCDEM's XXXX, looks after the local team in their Christchurch HQ. During an event, XXXX is responsible for supervising all the EOC/ECC staff and to, 'help the controller achieve their objectives they set out to respond to [an] emergency'. This gives XXXX a very direct involvement with decisions made within an EOC environment, and how tasks to be completed and the intelligence available interconnect.
- As with Interview 2, confirmation of previous points. XXXX also mentioned that in his role the tasks on the ground are his focus.
- In XXXX role, XXXX, being task orientated, views information in relation to what XXXX team needs to know in order to achieve their goals. To this end, within the flow of information, XXXX will engage within XXXX team and task people with gathering information to facilitate planning and making decisions around tasks. This involves working with GIS operators, and can include tasks such as creating maps, or producing statistics around a disaster. To accomplish this, data are drawn from internal sources such as the Canterbury council map database, and from external sources, such as partner agencies and the local councils who are affected (within the interagency network

mentioned in Interview 2). There is also an element of crowdsourced information that is generated from the Public Information Managers who monitor social media, and who will sometimes pass on individual posts or provide reports on trends in the data.

- The data that are most valuable for the work XXXX does are reports concerning elements which civil defence teams can address. These data then, outside of a general understanding such as roads and properties, is information that helps create a picture of the situation on the ground. This is information about areas, streets and potentially houses impacted by a natural event. Additionally, this information is set beside event specific information, rainfall and low-lying areas in flooding, forested areas with housing in fires, displaced peoples, etc. Information of this nature can be then used to respond, and is also aggregated into situation reports that go to the government.
- In terms of data limitations, similar to XXXX's remarks, XXXX notes that data are generated by aggregation through the different levels of government. This extends from the TA level, who are responsible for collecting information on people, property and infrastructure in this local areas, and up through regional authorities to a national level. In this, XXXX notes that the issue is that it is reliant on a large amount of manual collection and processing of data, and for local TAs to have collected all of the relevant information before a disaster occurs. This is particularly problematic, as XXXX also notes that in Canterbury, each TA has their own systems and policies, which makes the regional information strategy more difficult from a funding point of view.
- XXXX believes that electronic platforms should be being used more, not only to help individual people understand what is happening, but also to contribute information about how they need help. XXXX implies that this form of crowdsourcing for disaster response would be an effective method, particularly if these data can be aggregated to understand the bigger picture. When asked for examples, XXXX spoke of the use of geotagged photos to identify issues. Additionally, citizen based reporting could help identify problems, with those photos allowing for validation remotely.
- Advocating for the advantage that a human factor brings to data from crowdsourcing, XXXX uses an example where technical systems generated information that was misused. This was during the 2011 Christchurch earthquake when CCDEM realised that there were areas without working sewerage. In response, a plan was enacted to deliver port-a-loos to those houses affected, only to discover that those houses had also been abandoned by their occupants. This event happened because of systems not being

connected, and XXXX believes that with crowdsourcing, there is the ability for a common sense approach that would have information for councils come with caveats such as, “we have no working toilets but we also are not living there”.

- XXXX mentions that XXXX has seen councils getting better at using websites such as Survey123 to collect information. This happens either in the form of staff members doing door-to-door surveys in affected areas, or by people voluntarily filling out these surveys to communicate how they have been affected themselves. This was seen in the Edgecumbe Floods, and during the Kaikōura Earthquake, with the then New Zealand Fire Service and their Urban Search and Rescue Teams using Survey123 for rapid building assessment. That data were then applied very quickly as a layer in a GIS, meaning that each property could be searched and its status displayed, or the data aggregated to see patterns. This same technology has the potential to be applied to public engagement for crowdsourcing. At this point in time however, CCDEM has not engaged with this technology. XXXX also notes that the implementation should be directed at a national level to ensure consistency in process and information.
- When talking about a hypothetical national level crowdsourcing system or campaign, XXXX mentioned the scale of information to be collected as a potential problem. Specifically, XXXX notes that during a disaster, it will be an even greater amount of information to work through, although it would be considerably more valuable, as it is also real-time, and therefore current. This would, however, result in an increase to labour or technical pressure that is currently not part of CCDEM workflow. As with XXXX’s interview, the next step for CCDEM is to look at how a public engagement forum such as Survey123, or a custom web service, can be integrated into the CCDEM systems. XXXX, however, holds the view that crowdsourcing, to be as effective as it can be, should be implemented at a national level; this would ensure consistency.
- XXXX notes the value of engaging with the public through crowdsourcing, as it helps them understand the situation, and brings both piece of mind, and information to all parties. In regards to working with crowdsourcing groups, this was not discussed as much as in previous interviews, as the focus was on creating that public engagement which XXXX values very highly.

Themes:

- The highest value data is information around where people are in need (temporal importance).
- Issues in consolidating data from TAs to a CDEM regional EOC.
- Almost all information is useful for creation situational awareness.
- Crowdsourced data through geotagged photos highlighted as a useful source.
- Crowdsourcing provides a level of detail and common sense that is missed in purely technical systems.
- Crowdsourcing to be effective needs to be implemented at a national scale to ensure consistency.
- The current CDEM systems are not designed to handle the large amount of changing data in a crowdsourced collection.
- Collaboration with volunteer crowdsourced groups essential for positive outcomes.
- Use of online surveys to crowdsourced viewed as a next step.
- Social media is the primary method of crowdsourcing.

Interview 4: XXXX, Emergency Management Otago, 24th August 2017

Method of interview: Zoom teleconference

- XXXX as the Dunedin XXXX is responsible for XXXX Dunedin City Council's response team. In this role, XXXX is involved in decision making and working directly with the Incident Controller (a Council-appointed senior executive) to help them understand the processes around disaster response systems. This experience extends to an understanding of what is needed, both from a response team perspective, and also from an intelligence requirements perspective.
- XXXX works at the TA level for Dunedin, meaning that XXXX has a good understanding of how information flows can impact the response operations in a very direct manner. As with other CDEM organisations, the Dunedin team functions in the same EOC manner.
- Working at the TA level, XXXX talks about information about Dunedin that will impact response operations. This information needs to have a high level of detail, as every step of a response operation in Dunedin goes through the Dunedin Controller,

and therefore XXXX. In this interview, XXXX outlined the information requirements for a disaster response operation as including the following:

  - Natural Hazard vulnerabilities – relief that can impact flooding, isolated areas, weather patterns.
  - Key infrastructure to the city – Power, water and communications; emergency service facilities, civil defence facilities, roading and transportation.
  - Contact information for key infrastructure.

- The information that is already within the system is generally uploaded to a council-owned GIS system that can be used by different agencies during a disaster. XXXX says that the purpose of this is to facilitate the decision making process by centralising this information.
- To source this information, XXXX uses existing databases that council has, but also through collaboration with other organisations; the Otago Regional Council has hazard risk information that goes into this system, and local utility companies provide data on key infrastructure that may be needed during a disaster. When asked about possible improvements to the data, XXXX said that the data are always being refined, particularly as policies change over time. For example, 10 years ago, a policy changed, and local primary schools were predesignated as civil defence locations. This policy changed 5 years after that to be whatever structure is suitable on the day. In either instance, the data requirements for the council response team changed, and so did the dataset identifying potential locations. The council GIS system is, in this sense, a constantly improving system.
- The strengths of this system, XXXX says, lie in the strong base of useful information from the variety of layers available. For example, identification of potential hazard areas, and matching that with any other data available, is made possible by this system. However, this system presents with a notable weakness that when it comes to data during a disaster, particularly when narrowing it down from areas that are potentially threatened to areas currently impacted by a disaster. This information, naturally, cannot exist before a disaster. To source this information during a disaster, field reconnaissance teams will report back on the situation on the ground, and this can be used to further narrow down areas from potentially threatened to actually threaten. However, these teams are limited by council resources, and while modern technology means that this communication is fairly instant, the teams can still only report on what is directly in

front of them. This means that the speed of information is limited not by technology, but by the level of the council team's presence on the ground.

- An interesting observation from XXXX is that even information from council teams can have issues. For example, a report of a street needing evacuation, because of heavy surface road flooding, may actually not fully represent the complete picture of how that flooding has impacted the residents of that street. In the example given, XXXX says that while it may appear that a street needs evacuation from the road, the houses themselves may not have had habitable living space compromised, and that information requires a more in-depth investigation to find out. This relates back to the issues around both time, and personnel resources in all disaster events.
- One element of information XXXX discusses is public understanding; what information the general public has regarding a disaster, and how they are getting this information. One example of this was a notification of a water contamination issue by the Dunedin City Council (DCC). This issue was related to the reservoir supply and the need to test for a mild form of contamination. The public perception however, facilitated by rumour and speculation on social media, was that it was a 1080 poison contamination. While this was easily fixed by sharing the correct information through social media and official channels, it does highlight the need to understand the public perception of the information they are receiving. This is particularly so when that information is not coming from official sources. This has relevance to crowdsourcing, in that some systems of crowdsourcing allow people to share not just with response agencies, but also with each other. This has the potential to be a source of information for Mr. Mitchell's council team, as well as a source of misinformation for the public.
- When asked about what XXXX definition of crowdsourcing was, XXXX said that it was 'instant access to untested information, generally from the public, in relation to a given event'. At present, the Dunedin team is engaging with the social media side of crowdsourced data. This is done though their social media team, which is set up in response to events. XXXX opinion on this particular source is that, with specific reference to Facebook, social media provides instant information about people impacted by a disaster, however this information is unverified. The unverified nature, he notes, limits what actions can be taken from the data gained. Unsolicited information is also gained through people contacting the council to report issues. However, this is generally discouraged, as Council prefers to have people contact emergency services

for issues that are an imminent threat, or to contact utility providers when applicable, as they are more able to resolve issues related to their business.

- When the team does use crowdsourced data, particularly from social media, the information is not taken at face value. As such, they will often look for corroborating data, and provide a "measured response". XXXX provides an example of where this happened during a disaster in the June (2015) floods: 'As the operations centre was winding down for the night, a message popped up on Facebook about a slip threatening a house. This caused concern, and we were very quickly able to identify the location and get in touch with the property owner, and ascertain that the slip had occurred three days ago and had been addressed. So, it does raise some concerns around what level of response you would give to an image or a post on social media'. This highlights the heightened awareness the Dunedin team has around misinformation on crowdsourced platforms.
- During our discussion, the idea of the method of information sharing having an association with its trustworthiness. Specifically, XXXX noted that information provided directly by the public through a phone call is usually viewed favourably in terms of trust in the information provided. The reason for this is that for someone to provide said information through a phone call requires a considerable amount of effort on their part; waiting for someone to answer, and then being redirected to a person to talk to. Additionally, any information that they do provide is immediately associated with their phone number, and presumably them as a person. These two factors mean that information from a phone call is generally considered to be less prone to contain misinformation, or at least intentional misinformation. The inverse of this is the team's interactions with crowdsourced data through social media, which are more prone to opinions or information from those less informed, similar to posts about 1080 in the water, as mentioned previously.
- Future plans for crowdsourcing are generally on hold for the Dunedin team. The reason for this is that other CDEM teams are currently working through this question and developing crowdsourced platforms. Specifically, Mr. Mitchell mentions the work being done by XXXX at Emergency Management Southland, who is developing a crowdsourced application for the people of that region.
- When asked about how the Dunedin team would be able to work with outside crowdsources, XXXX said that a collaboration would be considered. However, he is

not sure of how readily it would be adopted during a disaster as 'realistically [the Dunedin team] are only starting to mature ourselves in terms of our intelligence processes'. XXXX says this in the framed example of a group with Ushahidi crisis mappers creating a complex and highly detailed crowdsourced dataset, a dataset that may be outside of the current scope of Dunedin's intelligence team to process. Additionally there is another factor, particularly for social media, in that crowdsourcing requires two way communication. This means that anyone involved in collecting data would need to be familiar with the systems used and to be directly connected to the operations centre for live problem solving.

Themes:

- The highest value data is information around where people are in need (temporal importance).
- Almost all information is useful for creation situational awareness.
- Crowdsourced data through geotagged photos highlighted as a useful source.
- Crowdsourcing is still a new field and Civil Defence is in the early stages of utilising it.
- Crowdsourcing needs to be two way communication to address issues as they arise.
- Social media is the primary method of crowdsourcing.

Interview 5: XXXX, New Zealand Red Cross, 28th August 2017

Method of interview: Zoom teleconference

- XXXX is one of the XXXX of the NZRC. In this role, XXXX is part of the policy decision making process. XXXX has also spent several years inside of NZRC's Disaster Welfare Support Teams (DWST) giving XXXX an understanding of NZRC's capabilities. Importantly, XXXX does specify that he is not involved as much in the technical aspects of NZRC's use of geospatial technology.
- NZRC as put by XXXX; 'NZRC has a number of guiding principles, but it is all based in the mission to improve the lives of vulnerable people, and mobilise the power of humanity. As part of that, we have arrangements with the [New Zealand] Government through our auxiliary status as a provider of support during a disaster; something which we have a remit to do internationally as Red Cross. This means that the NZRC is

included as part of emergency management and disaster response plans under CDEM as a responding organisation with civil defence powers in an emergency. Additionally, as an organisation independent of the New Zealand Government, NZRC has the ability to self-activate to respond to natural disasters in which people may experience suffering.

- From a technical GIS and intelligence standpoint, which XXXX does stress he is not an expert on, NZRC typically has a limited function. XXXX attributes this to their core objective of alleviating the suffering of people in need, and the existence of CDEM planning and intelligence inside of the EOC systems they work within. As such, from XXXX's experience, NZRC teams in New Zealand are primarily end users of information that is produced from CDEM. An important caveat on this statement is that this applies during the response phase when NZRC is integrated into a CIMS structure, and takes the role of a responding agency similar to emergency services. During the recovery phase, NZRC takes on a different role, and this stage does change their approach to intelligence and information collection, particularly regarding the measuring of the impact of support to communities.
- Information requirements of the NZRC differ drastically between Response and Recovery phases. The reason for this difference is that between the Response and Recovery phases, the activities undertaken are completely different. During the Response phase, NZRC teams are part of CIMS as a response agency, and conduct activities such as welfare centres, light search and rescue, delivery of aid, evacuation of impacted people, and other activities CDEM requires an agency to facilitate. This changes significantly during a Recovery phase when NZRC becomes more self-directed, and guided by internal management and the mandate to alleviate suffering. The following section is divided into Response and Recovery:
- *Response*: NZRC collects information from its outreach processes (door knocking) that is then used to supplement their understanding of where people need help. This is supported by registration systems in NZRC welfare centres, which during the 2011 Christchurch earthquake were manually entered initially into spreadsheets, and later into basic GIS formats. This information was used to add to the reports and updates produced by CDEM in the EOC, with this information being part of those reports.
- *Recovery*: The Recovery phase uses the same sources of information as the Response phase to assess areas of need. However, XXXX noted that within the long term

approach of recovery, particularly for the primary case study of Christchurch, additional data sources were sought to better understand the impact they had on communities. These data sources came from extended community outreach beyond the response phase of the disaster. Additionally, "comprehensive" surveys were used as part of this approach, an element that XXXX believes the NZRC excels at.

- On the subject of crowdsourcing, XXXX said that it is not a large focus of the NZRC, and attributes this to the idea that people most vulnerable – those that the NZRC focus on – often will not have access to the technological systems most crowdsourcing takes place through. This is not to say that people are unable to access social media or crowdsourcing websites under normal conditions, but instead to say that during a disaster, those worst affected may not have access to power, cell tower signal, or the means to travel to a place to ask for help. Effectively, the people the NZRC will focus on, are those who are the worst impacted by a natural event.
- XXXX reinforced that in the context of the work NZRC does, crowdsourcing carries the perceived risk of collecting information not reflective of those most vulnerable. For example, XXXX mentions that when making decisions around the spending of recovery funds, they needed to ensure it was going to those in the most need. From that perspective, crowdsourcing information on who has been impacted could mean that the focus turned to those with access to contribute to the crowdsourcing, to the exclusion of some who may be even worse off to the point of not having mechanisms to contribute at all. By using NZRC surveys, they could ensure all areas were equally represented to collect this information.
- NZRC, as of 2017, is trialling a system called Magpi for field data collection. This is, in essence, a mobile application which has premade – ideally by a user in the EOC – survey forms that can be geotagged. The forms, completed by field teams interviewing residents in an affected area, are then uploaded to a central GIS that displays the information live at an EOC. This is not strictly crowdsourcing as it involves using a professional to ask and record information, but the technology involved is similar to that of crowdsourced applications. This does, however, represent an increase in the speed of data collection from people in an affected area, to the decision makers.
- Additionally to the implementation of Magpi, NZRC is also looking at the implementation of a GIS/incident management system that is currently deployed by the International Federation of the Red Cross and Red Crescent Societies (IFRC). This

system is called the RMS (Resource Management System), and is a GIS system deployed by the IFRC to local branches to give them the capability to visualise where branch members are located in a disaster area. It has not been used in New Zealand yet, as it is still being investigated by NZRC for its usability.

- Looking towards the future, XXXX does see a future of crowdsourced for response operations, however generally cautions against information being used in disaster response that is not verified.
- On the subject of community engagement, XXXX spoke about NZRC's deep ties to communities. He said that with NZRC members being part of communities across New Zealand, when disasters occur, Disaster Welfare Support teams (DWST) are often engaging with communities before the government can even declare an emergency. This puts NZRC in a position where they are able to engage with grass root community groups where they form.

Themes:

- The primary method of collection is field surveys through response teams.
- Information is generally acquired through CIMS (and therefore CDEM).
- Crowdsourced data carries the risk of excluding those most vulnerable.

Interview 6: XXXX, GNZ, 28th August 2017

Method of interview: Zoom teleconference

- XXXX is the XXXX for GNZ. XXXX is responsible for foundation production (topographic, aeronautical, and maritime data sets). From a disaster response perspective, XXXX is involved in data acquisition for GNZ efforts. This gives XXXX an in-depth understanding of what processes are involved in data acquisition, and how crowdsourced data could potentially fit into GNZ processes.
- XXXX notes that at this stage both the technologies for quickly sharing data, as well as high quality foundation data exist. This, XXXX believes, has improved disaster response operations to move more quickly and act on new data more effectively.
- XXXX defines crowdsourced data as users from a range of backgrounds coming together to provide information about the world. In regards to GNZ response, OpenStreetMap has been used in conjunction with other sources of data. Additionally,

XXXX notes the value of social media and traditional news media as a 'very useful source of context and a gauge of the severity of an event'. Crowdsourced data in GNZ are characterised as data which are used to provide context and situational awareness. Importantly, the data are not used in isolation.

- In support of Crowdsourcing being used by GNZ is a held attitude that new sources of information are regularly investigated for usability. This is with the caveat, however, that new sources from unknown producers need to be validated before they can be used in a decision making process. Furthermore, XXXX said that decision makers will naturally gravitate to where the information they are looking for is available. This means that crowdsourced data, as it becomes more common-place, is going to be part of future operations
- During our discussion, the topic of variation in information provided by individuals came up. To this end, XXXX noted that individual perceptions can influence the nature of the information received. For example, if asked "how much water do you have left?" this could be answered in a variety of ways; depending on a person's background they may take more conservative or liberal estimates, which can lead to a poor quality of information for decisions around resource allocation.
- When asked about future use of crowdsourced data, XXXX noted the importance of this as a growing field. To this end he believes that crowdsourced data will continue to be used, however the exact nature of the future of crowdsourced data in GNZ remains unclear. Additionally, GNZ has done some testing of mobile apps and their applicability to GNZ operations. To this end, it has not been done with crowdsourcing specifically in mind, however this is certainly a possibility (conditional on policy).
- Regarding developing relationships with other groups, XXXX spoke of the ongoing efforts by GNZ to develop good connections in this area. XXXX said that while GNZ has good working relationships with other agencies in New Zealand, this work is an ongoing process. This is relevant, as during a disaster, organisations are not acting alone, and the sharing of information and methods is the best way to achieve results. This work does have policy challenges, as working in a live environment is more complex, but these are 'not insurmountable'.
- Finally, XXXX noted that while he was not aware of any specific occasions where GNZ created a relationship with a crowdsourcing group, there have been local engagements of a crowdsourced nature. The engagements XXXX refers to are situations where

NZDF personnel will interact with local populations to find out information, and use that information for situational awareness. Therefore, the principle of engaging with the public to gain an understanding of the situation on the ground is not a new concept. For this reason, XXXX believes that a more technologically-based form of engagement, such as crowdsourced apps, have considerable potential.

Themes:

- Working between response agencies is a focus of future policy.
- Existing use of reputable source of crowdsourced data, OpenStreetMap.
- Crowdsourcing viewed as essential to future disaster response efforts.
- Issues of accuracy of crowdsourced data not as much of a concern as it is used for either situational awareness of confirmation of other information.
- NZDF focuses on situational awareness over specific incident management.

Interview 7: XXXX , Ngāi Tahu, 11th September 2017

Method of interview: Zoom teleconference

- XXXX is XXXX for Ngāi Tahu. Within this department disaster recovery and response is part of this. XXXX work spans across the four Rs, and he is a policy maker. This puts XXXX in a position to comment on Ngāi Tahu's involvement in disasters within areas the Iwi has members.
- Ngāi Tahu is a Statutory Partner in the recovery of the 2011 Christchurch Earthquake, along with the three local TAs impacted, and led by CERA (Christchurch Earthquake Recovery Authority). Being a statutory partner, this came with responsibilities in the recovery effort, as well as some powers afforded under CERA legislation. This is in addition to direct and indirect support to members of the Iwi impacted by the disaster, through support of local business, and grants, or working with NGOs.
- XXXX noted that in the first instance of a disaster, being able to contact people is of a very high priority. Knowing where community members live, and their contact numbers, becomes very important, especially if you also know that the area where they live has been impacted by a natural event. Uniquely, this is something which Ngāi Tahu – through their GIS team – have; registrars for Iwi members. This has allowed for very quick contact during natural events. XXXX estimates that around 10% of member

addresses are known currently. The system in question had been in place pre-2011, but underwent a major overhaul after the 2011 earthquakes. These data have been collected directly by Ngāi Tahu.

- To collect information during disasters, Ngāi Tahu conducted field surveys in a similar fashion to CDEM and the NZRC. After disasters, a more open forum has been used in terms of community engagement; community meetings. In general however, Ngāi Tahu, from this interview, has not focused on crowdsourced data in terms of disaster management. This is because the focus of Ngāi Tahu is to assist Iwi members, and this has been done through community connections.
- An element of crowdsourced data, XXXX notes, is that when it comes directly from the community, it is unfiltered. In his opinion, when looking at information to respond to disasters and help communities, unfiltered information can prevent bias or 'spin' being placed on information flows. This is viewed positively.
- Crowdsourcing is not a large focus for Ngāi Tahu outside of direct community engagement.
- One element which was spoken about in great length, was the ways in which Ngāi Tahu engages with its community. Internal connections within the tribe have allowed for a good understanding of the conditions members were living in after the earthquake. This was supported by surveys being conducted to gather information. Following this information gathering process JAGs (Joint Action Groups) were set up. These were set up as both a planning committee, and as a form of community engagement ensuring that local communities had input into the plans created. This local engagement would be done through Kaitokou* (team surveyors), sometimes assisted by NGOs.

Themes:

- Internal collection of member databases creates a strong foundation for post disaster assessment of damage and harm.
- Door to door surveys are used in place of other methods of data collection.
- Social Media is used to understand the situation, however that is the extent to which crowdsourced data is used for community wellbeing.
- Crowdsourced data is noted to be unbiased data as it reflects what concerns the community.

Interview 8: XXXX, GNZ, 12th September 2017

Method of interview: Zoom Teleconference

- XXXX is a data manager for GNZ and as such is very familiar with data sources and has personal experience with crowdsourcing theory. Specifically with involvement with a group called MapAction, which is a network for geospatial professionals working in disaster response.
- In addition to what was mentioned by other GNZ employees XXXX emphasised how working within a secure data system means that where the information comes from needs to be considered. This is for security as well as reliability reasons. This challenge is overcome somewhat by working within CDEM networks which are unclassified. This was exemplified in the case of the 2016 Kaikōura earthquakes where NZDF personnel found difficulties connecting back to GNZ with information as it was done under a civilian information network set up by CDEM.
- Adding to XXXX's explanation of what data is used and the challenges faced, is the emphasis on how the South-West Pacific region impacts the work GNZ does. As an aside, not necessarily domestic but still engage with by the New Zealand government, GNZ finds that OpenStreetMap has been an excellent resource in the South-West Pacific where at times data is not as available as in New Zealand.
- XXXX as a person who has worked with crowdsourced data before is very familiar with this data. Interesting they advocated for their teams understanding of crowdsourced data to and explained that while it is not used extensively by GNZ (related to the role they have, see previous GNZ interviews) it is well understood. Regarding how it fits into GNZ data, as data manger XXXX is always open to adding new sources of data to the range GNZ uses.
- An area of interest for XXXX was in the uses of TomNod to analyse imagery (a primary source for GNZ). Within GNZ they have trained staff to look through, analyse, and add features to imagery. However it is recognised that with any major operation the work load can increase beyond normal capacity and crowdsourcing has been effective overseas to process this large amount of imagery.
- The big perceived limitation for crowdsourcing from XXXX's perspective is that it is very difficult to fit within NZDF systems.
- Regarding the future of crowdsourced data within GNZ XXXX is open to the possibility of using CGI in operations but it would have to be of benefit to GNZ. The issue with

this is that much of the work GNZ does within an event is not applicable to the type of data produced. Where there would be most crossover would be in imagery analysis but this is covered well within GNZ.

- As for relationships with outside groups and GNZ, there is no direct connections. As currently the role GNZ has in a disaster does not fit well with crowdsourced data produced.

Themes:

- GNZ's secure environment poses challenges for working with crowdsourced data
- Crowdsourced data will well understood
- There is no engagement with outside crowdsourced groups
- Crowdsourced data is not very applicable to GNZ outside of crowdsourced processing of imagery but this is currently able to be covered in-house.

Interview 9: XXXX, Emergency Management Southland, 13th September 2017

Method: Zoom Teleconference

- This interview was conducted between XXXX and YYYY. XXXX is a GIS analyst at Emergency Management Southland and YYYY is an emergency management advisor at Emergency Management Southland. Emergency Management Southland is the CDEM group for the Southland region.
- The scope of the work conducted by XXXX and YYYY is similar to other regional CDEM's but notably Emergency Management Southland is working towards developing a more 'logic-driven' intelligence gathering system, finding more effective sources of timely information. Crowdsourcing is part of this.
- Current sources of information from Emergency Management Southland as YYYY explains is the same as other CDEM's however as YYYY explains "there are no specific documentation on how to collect intelligence" and they instead work from experience and known sources. These are important to disaster response but existing sources could be timelier in their data.
- XXXX and YYYY view crowdsourcing as the general public being able to contribute to an event by sharing their observations. This view is heavily reflected in their model

for crowdsourcing. This model is a working prototype of an EOC controlled, web-based, crowdsourcing platform.

- When asked about issues around crowdsourcing XXXX explained that many of the issues they would anticipant, inaccurate or irrelevant information, have been at least partially mitigated through their system. Through the use of 'dropdown tabs' and verification of major points they can guide information to deliver what is needed by responders.
- The system proposed, and the future of crowdsourcing for Emergency Management Southland, is a web-based user interface for Southland residents to contribute during an event. The system works through a portal through the Emergency Management website and go to an interactive map where they can post a report. Notably this process also provides the ability to post images, which YYYY says makes it easy to verify information in the tests they have done. The functionality of this crowdsourced system includes be ability for EOC users to re-post select information to this map.
- As for engaging with outside crowdsourcing groups this is viewed positively. Although this system has no functionality to allow for crowdsourced processing this is something XXXX and YYYY have thought about.

Themes:

- Better sources of data should always be sought
- A system is being tested that is direct crowdsourcing
    - The system has been a success in early tests
- Systems should be designed around the data needed and good design can mitigate some issues with crowdsourced data.

Appendix C: University of Canterbury Human Ethics Committee approval letter

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2016/123

10 July 2017

Andrew Wayne Cunningham
Geography
UNIVERSITY OF CANTERBURY

Dear Andrew

The Human Ethics Committee advises that your research proposal "How can Information from Crowdsourcing be Applied by New Zealand Disaster Response Organisations?" has been considered and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your emails of 19th May, 21st June and 4th July 2017.

Best wishes for your project.

Yours sincerely

pp. R. Robinson

Associate Professor Jane Maidment
Chair
University of Canterbury Human Ethics Committee

Appendix D: University of Canterbury Ngāi Tahu Research Centre approval letter

Ngāi Tahu Consultation and Engagement Group

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

15/03/2017

Tēnā koe, Andrew and Matthew

RE: How can information from crowdsourcing be applied by Aotearoa/New Zealand disaster response organisations?

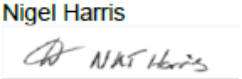
This letter is written on behalf of the Ngāi Tahu Consultation and Engagement Group. I/We have read and considered your proposal and acknowledge that this is a worthwhile and interesting project there have been no issues identified.

It is well considered and the researcher is clear about how they ought to take participants' (cultural) needs into account if and when applicable. It is also clear that ethics has been cleared from both Universities.

Thank you for engaging with the Māori consultation process. This will strengthen your research proposal, support the University's Strategy for Māori Development, and increase the likelihood of success with external engagement. It will also increase the likelihood that the outcomes of your research will be of benefit to Māori communities. We wish you all the best with your current project and look forward to hearing about future research plans.

The Ngāi Tahu Consultation and Engagement Group would appreciate a summary of your findings on completion of the current project. Please feel free to contact me if you have any questions.

Ngā mihi
Nigel Harris



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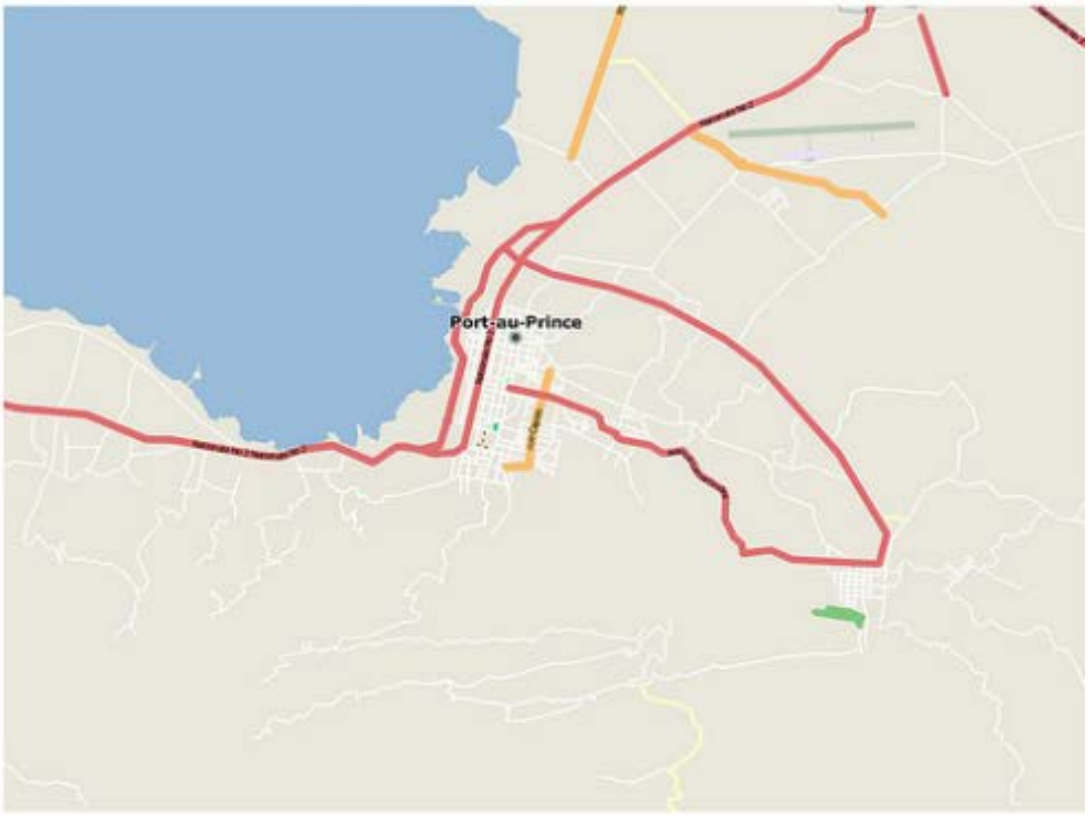
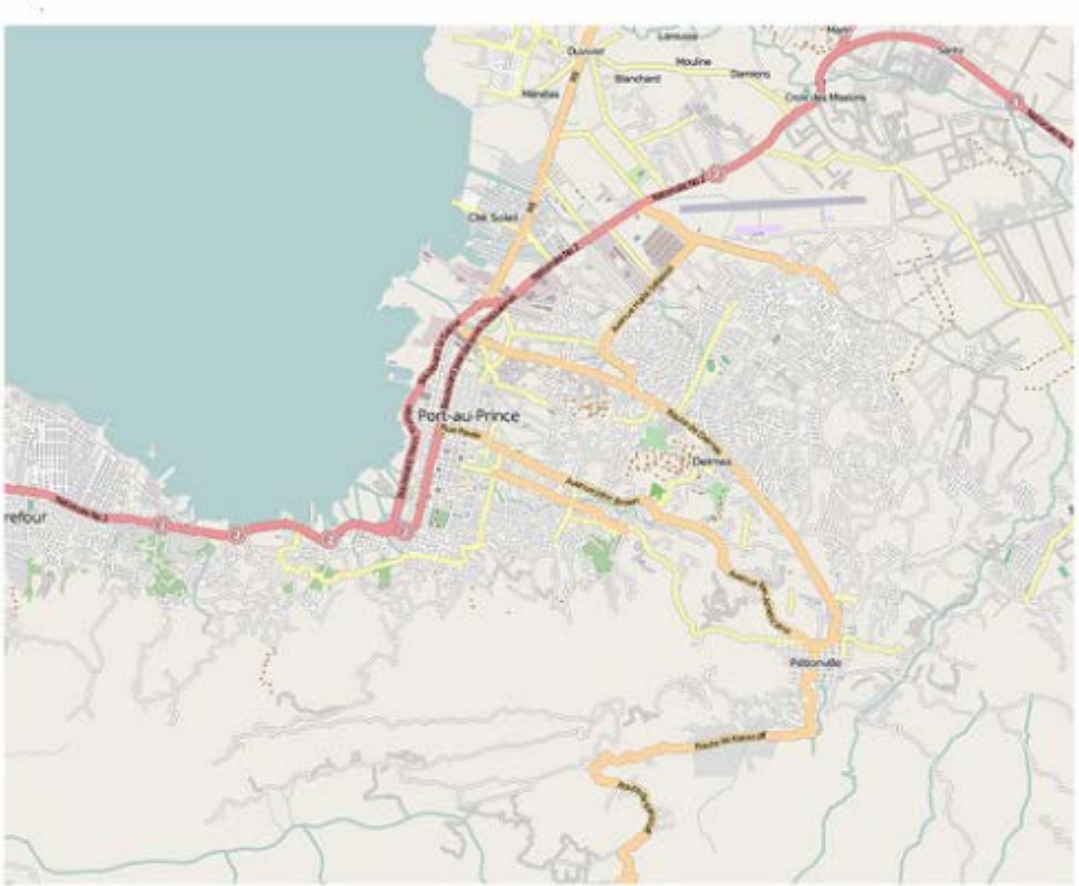
Appendix E: OpenStreetMap before (top) and after (bottom) 2010 Haiti HOT intervention, from Zook et al. (2010)





Appendix F: Assessment of effectiveness of crowdsourcing from aerial photography, from Ghosh et al. (2011)

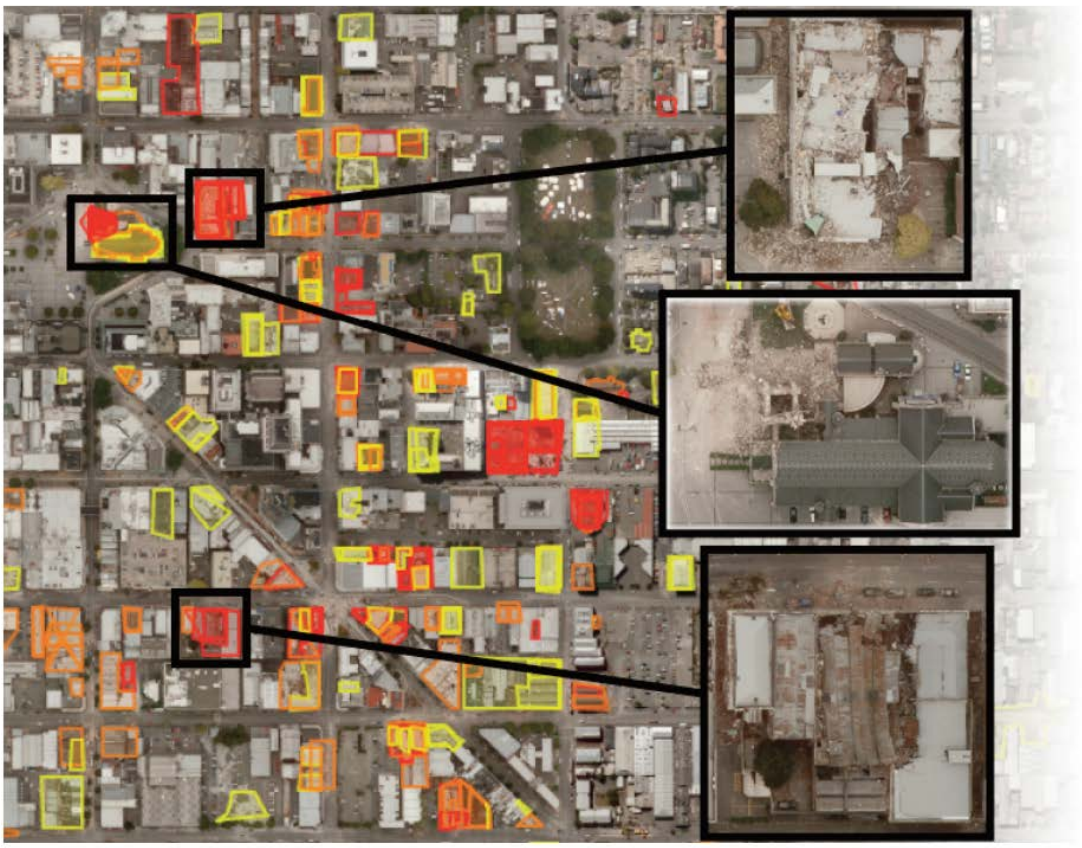


Figure 3. Sample of crowdsourced damage map of Christchurch, New Zealand. Each polygon was drawn by a crowd contributor and marked with a damage level (**red**: complete destruction, **orange**: very heavy damage, **yellow**: substantial damage). Three locations of crowd consensus are highlighted on the right, revealing reliable damage assessments.